STANDARD
FIRE CONTROL SYMBOLS

31 MAY 1950

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DEPARTMENT OF THE NAVY
BUREAU OF ORDNANCE
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RESTRICTED

ORDNANCE PAMPHLET 1700

STANDARD FIRE CONTROL SYMBOLS

1. Ordnance Pamphlet 1700 establishes a set of standard fire control symbols applicable to describing the fire control problem as solved by Naval fire control systems.

2. This publication serves two main purposes:

a. As a reference dictionary in which fire control symbols are listed alphabetically, defined, and illustrated; and

b. As a reference handbook in which related terms are grouped and distinctions among them clearly defined and illustrated.

Thus, Ordnance Pamphlet 1700 is intended for use by all Naval personnel in their study of ordnance equipment and instruction material. It is also intended for use by design personnel as a guide for their preparation of suitable instruction material.

3. The first issue of OP 1700 is limited to symbolization of the quantities applicable to solutions of the gun fire control problem. Subsequent revisions are expected to include subsurface and missile fire control symbols.

4. Ordnance Pamphlet 1700, when completed, will supersede OD 3447. The present edition of OP 1700 supersedes the surface and antiaircraft sections of OD 3447.

5. This publication is RESTRICTED and shall be safeguarded in accordance with the security provisions of U. S. Navy Regulations. It is forbidden to make extracts from or to copy this classified document without specific approval of the Chief of Naval Operations or originator, as applicable, except as provided for in article 9-10 of the United States Navy Security Manual for Classified Matter.

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Rear Admiral, U. S. Navy
Chief, Bureau of Ordnance

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STANDARD FIRE CONTROL SYMBOLS

Introduction

This pamphlet establishes a system of symbols and definitions for the surface, antiaircraft, and underwater fire control problems. It includes mathematical quantities associated with the geometrical analysis, and computational and mechanization quantities involved in solving these problems by fire control equipments. Fire control terms, with their accepted definitions and graphic symbols for mechanical and electrical devices, are included.

Standards established for symbols and definitions in this pamphlet should be followed in the preparation, use, and study of all ordnance publications, data, drawings, and correspondence. If quantities not previously symbolized are used, new symbols shall be constructed in accordance with the pattern formulated in this book. New symbols and definitions which may be required should be submitted to the Bureau of Ordnance for approval.

This book comprises the following four parts:

1. Symbol system, explaining how symbols are formed, how they are modified to denote special kinds of quantities, and how symbols for new quantities may be constructed.

2. Antiaircraft related quantities for use in work on specific parts of the gun fire control problem where it is desired to have on hand all values used to express a basic quantity. Special problems arising in the use of symbols are explained here. Separate chapters are used for the steps of the gun fire control problem.

3. Dictionary of symbols for quantities currently in use, or whose future use may be anticipated, arranged alphabetically.

4. Appendices of letters with their meanings when used as basic symbols, basic symbol modifiers, and quantity modifiers, arranged alphabetically.

SYMBOL SYSTEM

Contents

SYMBOL SYSTEM

INTRODUCTION

This part of the pamphlet explains the types of quantities symbolized, the way in which symbols for these quantities are constructed, and the rules for forming new symbols. Each class of quantities is given with its name and the symbol used to represent it. Also included are the modifying letters and numerals with their meaning when used as basic symbol modifiers and when used as quantity modifiers.

SCOPE OF THE SYMBOL SYSTEM

The system is designed to include symbols for:

1. Geometrical quantities used in solving the general gun and underwater fire control problems

2. Quantities resulting from computations made in solving the fire control problem

3. Quantities resulting from mechanization in fire control equipments

The system makes available symbols for the geometrical elements necessary to express quantities used in existing fire control mechanisms, quantities used in research studies, and quantities likely to be useful in the future.

Geometrical Quantities

The quantities and geometrical elements symbolized are those necessary to express the following five steps in solving the general gun fire control problem:

1. Determination of present target position with respect to own ship, expressed in various coordinates, and considering parallax effects.

2. Determination of linear and angular movement and directions of movement between own ship and target, referred to various frames of reference, and considering parallax effects.

3. Expression of wind quantities.

4. Expression of linear and angular offsets resulting from ballistics and prediction.

5. Expression of orders positioning the gun along the line of fire, considering parallax effects.

Computational Quantities

The quantities symbolized are those necessary to express:

1. Portions of, and additions and corrections to geometrical quantities, such as deck tilt correction, increments, etc.

2. Methods by which geometrical quantities are obtained, as computed, designated, estimated, etc.

Computational quantities covered are those which in the mechanization of the geometrical quantities appear to have a general usefulness—for example, deck tilt correction or trunnion tilt correction. For the present, highly specialized computational quantities are not symbolized.

Mechanization Quantities

Mechanization quantities symbolized are those which are associated with geometrical quantities, although they may not be directly connected with them—for example, rate control quantities.

For the present, quantities resulting solely from instrumentation design, and having no association with geometrical quantities, are not symbolized—for example, the angle of tilt of the traverse and elevation gyros.

STRUCTURE OF THE SYMBOL SYSTEM

The plan of the symbol system follows the general pattern of the previous system of OD 3447 with modifications to permit new quantities to be introduced. However, the structure of the system allows for the accommodation of many additional primary quantities and new related secondary quantities arising from refined analyses. In addition, it has greater flexibility and wider application to advanced studies.

In planning the symbol system, the following objectives were established:

1. To select a system based on an easily understood theory of symbolization.
2. To accommodate, without ambiguity, all primary and related quantities now used.
3. To provide for application of standard procedure to include new quantities.
4. To choose characteristic symbols for easy mnemonic recognition. For example, B for bearing, E for elevation.
5. To select symbols capable of being typed conveniently on standard typewriters. For example, avoid Greek letters, subscripts, and special characters. Since standard typewriters have only a limited number of letters and signs useful as symbols, use primary symbols sparingly and make greater use of modifiers.
6. To use symbols not conflicting with conventional mathematical notation. For example, ***dR*** meaning "time rate of change of range" may be confused with "differential of ***R***." To eliminate difficulties arising from the use of ***d*** to indicate rates, use ***D***, (meaning d/dt), a symbol in agreement with mathematical notation.

Construction of Symbols for Geometrical Quantities

The geometrical quantities used in naval gun fire control are those quantities involved in the mathematical solution of the general fire control problem. Therefore, in determining quantities to be symbolized, consideration is first given to the steps in the solution of the gun fire control problem. These steps are listed under "Geometrical Quantities" in "Scope of the Symbol System" in this section.

In each of these steps, the geometrical quantities fall into certain main classes of quantities. Each of these main classes of quantities is represented by a class name. The basic geometrical quantity in each class is represented by a basic symbol. In each class, other geometrical quantities, besides the basic quantity, are expressed by applying modifiers to the basic symbol. These modifiers express the way in which the quantity is measured.

For example, a class of quantities used in expressing present target position is linear distance between own ship and target. This class of quantities is called "Ranges." The basic geometrical quantity in this class is the linear distance between own ship and target measured along the line of sight which is expressed by the basic symbol ***R***. Another quantity in this class is the linear distance between own ship and target measured in the deck plane. This quantity is symbolized by applying the modifier ***d*** (meaning measured in the deck plane) to the basic range symbol ***R***, forming symbol ***Rd***.

Basic symbols and modifiers. The basic symbols assigned to represent the basic geometrical quantity in each class and the letters and numerals used to modify these basic symbols are:

Basic Symbols		**Modifiers**	
A	Angular Movement (Elevation)	***a***	apparent
		b	bearing
		d	deck
B	Bearing	***g***	gun
C	Course	***h***	horizontal
D	Rate of	***i***	inclination
E	Elevation	***k***	earth
Ei	Level	***o***	own ship
I	Inclination	***p***	prediction

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Basic Symbols		Modifiers	
J	Jump	***q***	heading
K		***r***	range
L	Sight Deflection	***s***	director
M	Linear Movement	***t***	target
P	Gun Parallax Displacement	***v***	vertical
		w	wind
Ps	Director Parallax Displacement	***x***	east-west
		y	north-south
R	Range	***z***	cross level
S	Angular Movement (Lateral)	***1***	present position
		2	future position
T	Time	***3***	advance position
U	Velocity	***4***	aiming position
V	Sight Angle	***5***	fuze
W	Wind Rate		
Z	Cross Level		

For a more detailed listing of the basic symbols and basic symbol modifiers refer to Appendices A and B.

In general, classes of quantities will be recognized by a single capital letter. However, in the case of level quantities the basic symbol ***Ei*** (meaning elevation due to inclination) was selected to indicate that level quantities are closely associated with elevation quantities. Similarly the basic symbol ***Ps*** was selected to indicate that director parallax displacements are closely associated with gun parallax displacements. The additional letter in these symbols is not considered a modifier, but as an assigned part of the basic symbol. Therefore these basic symbols are handled in the same way as any other basic symbol.

The exact meaning of some modifiers varies slightly in accordance with the basic symbol with which they are used. For example, modifier ***d*** (meaning deck) when used with basic symbol ***B*** means measured **in** deck plane, and when used with basic symbol E means measured **from** deck plane. The exact meanings of the modifiers along with their order of application when used with each basic symbol is given in the second part, "Related Quantities."

Quantity modifiers. Besides the geometrical quantities in each class, the portions of these quantities measured to various positions and accounting for various effects are symbolized. Also, in the expression of rates, the frame of measurement of the rate is indicated. These quantity modifiers are applied by enclosing the symbols for the geometrical quantities in parentheses and preceding or following the parentheses with the quantity modifiers. For example, the portion of sight angle ***Vs*** accounting for the effect of wind is symbolized by enclosing the sight angle symbol ***Vs*** in parentheses, and preceding the parentheses with modifier ***w*** (meaning portion accounting for wind), forming symbol ***w***(***Vs***).

The meanings of the various letters when used as quantity modifiers of geometrical quantities are:

a	advance
b	ballistics
k	earth
m	relative motion
o	own ship
p	gun parallax
ps	director parallax
s	inertial
u	initial velocity loss
w	wind

For a more detailed listing of quantity modifiers, refer to Appendix C.

Construction of Symbols for Computation Quantities

To construct symbols, the required quantities are determined, and then symbolized by applying modifiers to the geometrical quantity with which they are associated. The required quantities are determined by considering the two divisions of computational quantities.

Additions to, and partial geometrical quantities. To symbolize partial quantities, the symbol for the total quantity is enclosed in parentheses and terminated by quantity modifier ***j***. For example, to express partial deck deflection, total deck deflection ***Ld'*** is enclosed in parentheses and followed by ***j***, becoming (***Ld'***)***j***. If the symbol for the total quantity already contains parentheses, the partial quantity is expressed by terminating the symbol with quantity modifier ***j***. For example, to express partial sight deflection due to relative motion, the symbol for the total quantity ***m***(***Ls***) is followed by ***j***, becoming ***m***(***Ls***)***j***.

To express computational additions, the symbol for the quantity to which the addition is being applied is enclosed in parentheses and preceded by modifier ***j***. For example, to express the addition to deck bearing ***Bd*** to obtain horizontal bearing ***B***, quantity ***Bd*** is enclosed in parentheses and preceded by ***j***, becoming ***j*(*Bd*)**; this quantity is deck tilt correction. To express the addition to sight angle ***Vs*** to account for deflection prediction, ***Vs*** is enclosed in parentheses and preceded by ***j***, becoming ***j*(*Vs*)**; this quantity is complementary error.

To express the corrections applied to gun elevation and gun train to compensate for cross-level (that is, trunnion tilt corrections); modifier ***z*** is applied to basic sight angle symbol ***V*** for the elevation correction, becoming ***Vz***, and to basic sight deflection symbol ***L*** for the train correction, becoming ***Lz***.

Methods by which geometrical quantities are obtained. To express the way in which a geometrical quantity is obtained, the symbol for the quantity is enclosed in parentheses and preceded by the appropriate modifier.

Quantity modifiers used are:

c ------------- computed or generated
d ------------- designated
e ------------- estimated
I ------------- initial
o ------------- observed or measured
s ------------- selected

For example, ***c*(*B*)** is computed relative target bearing, ***d*(*E*)** is designated target elevation, ***e*(*R*)** is estimated present range, ***I*(*R*)** is initial present range, ***o*(*E*)** is observed target elevation, and ***s*(*Ei*)** is selected level.

To express a corrective input or spot, the symbol for the quantity to which the corrective input is applied is enclosed in parentheses and preceded by quantity modifier ***q***. For example, range spot ***q*(*R3*)**, elevation spot ***q*(*Vs*)**, and deflection spot ***q*(*Ls*)**.

To express increments of a quantity Δ has been used in the past. To avoid Greek letters ***i*** is now used, and the symbol for the quantity is enclosed in parentheses and preceded by quantity modifier ***i***. For example, increment of present range is ***i*(*R*)**, and increment of computed relative target bearing is ***ic*(*B*)**.

To express prediction time, basic quantity ***T*** is modified by ***p***, becoming ***Tp***.

The computational quantities symbolized are those which represent the true value of the quantity. However, if a close approximation of the true value is made by empirical formula, this approximation is expressed by the same symbol as used for the true value of the quantity. For example, the symbol for the true value of deck tilt correction is ***j*(*Bd*)**. In all present equipments using this quantity, deck tilt correction is approximated by an empirical formula, however it is still symbolized as ***j*(*Bd*)**.

Construction of Symbols for Mechanization Quantities

Mechanization quantities are highly specialized values whose existence depends solely on:

1. The method used by the computing instrument to solve the gun fire control problem (such quantities are rate control values, gyro tilt angles, etc.)

2. The mechanization characteristics of the instrument (such quantities are smoothing values, solution time, and sight sensitivity, etc.)

These mechanization quantities are concerned mainly with the study of theoretical characteristics of fire control instruments, error analysis, and instrumentation design. They are not generally associated with the mathematical quantities involved in the geometrical analysis of the general fire control problem.

The defined values of these quantities are in most instances very general, and vary in accordance with the computing instrument with which they are associated. Therefore, it is impractical and difficult to represent these quantities with exacting symbols as is done for geometrical and computational quantities.

In general, since these quantities appear infrequently in the preparation, use, and study of ordnance publications, data, drawings, and correspondence, they are not symbolized in this book. However, in some special cases, mechanization quantities appear frequently due to the extensive employment in the Navy of a computing equipment using these quantities. In these cases, the mechanization quantities are symbolized. One such group of mechanization quantities are the rate control values used in the

regenerative prediction system of the Computer Mk 1.

Rate control quantities. To express the rate control correction to a quantity, the quantity is enclosed in parentheses and preceded by the quantity modifier ***r***. For example, the rate control correction to linear bearing rate ***DMb*** is ***r***(***DMb***), to linear elevation rate ***DMe*** is ***r***(***DMe***), and to range rate ***DMr*** is ***r***(***DMr***).

Rules for Forming New Symbols

The system provides symbols for basic quantities and their components, and geometrical elements for expressing them in reference frames and coordinates used in present equipments and considered in research. Due to limitations in letters and terms available for symbolizing quantities and expressing geometrical elements, quantities in these reference frames whose values have not been previously indicated are unsymbolized to maintain short symbols for the necessary or valuable quantities. Also, the system does not provide for symbolizing quantities measured in reference frames not previously used nor considered for use in research. However, the system is made as flexible as is practicable to provide exacting symbols for necessary or valuable quantities.

To construct new symbols, the following rules are provided:

1. Select the basic symbol given in this pamphlet for the class of quantity represented. For example, if the new quantity to be symbolized is a type of bearing, the basic symbol selected is ***B***.

2. Select modifying letters or numerals given in this pamphlet for the way in which the quantity is measured. For example, if the quantity to be symbolized is measured from, to, or about the line of fire, one of the modifiers selected is ***g***.

3. Apply the modifiers in the order established for that type of quantity in this pamphlet. For example, if the quantity to be symbolized is a bearing requiring modifiers ***d*** and ***g***, modifier ***d*** shall precede ***g*** in the formation of the symbol.

4. If no basic symbol or modifiers are available to express the quantity, select new letters or numerals which follow the specifications and which hold as nearly as practical with the pattern formulated in this pamphlet.

For example, if it should be required to express rate of motion between target and reference director along line of fire, modifier ***g***, used to refer quantities to line of fire, would be applied to this rate along line of sight ***DMr***, forming symbol ***DMrg***.

These rules are of a general nature since the requirements for terms and geometrical elements to express new quantities are in most instances unforeseeable. However, they are given to aid in maintaining a systematically developed set of symbols for use in solving the fire control problem.

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ANTIAIRCRAFT RELATED QUANTITIES

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ANTIAIRCRAFT RELATED QUANTITIES

Introduction

This part of the pamphlet discusses the requirements for symbols expressing the quantities involved in each step of the general gun fire control problem, and any difficulties which arise in symbolizing these quantities. Also, it establishes the standard symbols for all gun fire control quantities. For ready reference to the classes of quantites used in any specific part of the gun fire control problem, the classes (with all the individual quantities in each class) are compositely grouped under the part of the fire control problem in which they are involved. For example, if it is desired to have at hand the classes of quantities (with all the quantities in each class) used to express present target position, reference is made to the page or pages showing this group of quantities.

To accomplish this, this part is divided into five chapters; each chapter being one of the steps in the solution of the general gun fire control problem:

1. Present Target Position.
2. Motion.
3. Wind.
4. Linear and Angular Offsets.
5. Gun Orders.

Included in each chapter are:

1. The standard references and geometrical elements necessary to symbolize the quantities involved.
2. The classes of quantities with the basic symbol used to represent each.
3. The definition of the basic symbol when representing the basic quantity in each class.
4. The basic symbol modifiers and quantity modifiers with their exact meanings when used with each basic symbol.
5. Examples of the application of basic symbol modifiers and quantity modifiers when used with each basic symbol.
6. Composite illustrations and charts for each class of quantities, defining and symbolizing the quantities involved.

For clarity in designating planes in the composite illustrations, color-coding and letter designations are used. The colors and letters used are:

h	red	horizontal plane
d	green	deck plane
e	light blue	vertical plane
e′	yellow	normal plane
s	orange	slant plane through director elevation axis in horizontal plane
sd	purple	slant plane through director elevation axis in deck plane
g	brown	slant plane through gun elevation axis in horizontal plane
gd	indigo blue	slant plane through gun elevation axis in deck plane

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ANTIAIRCRAFT RELATED QUANTITIES

Chapter 1—Present Target Position

Contents

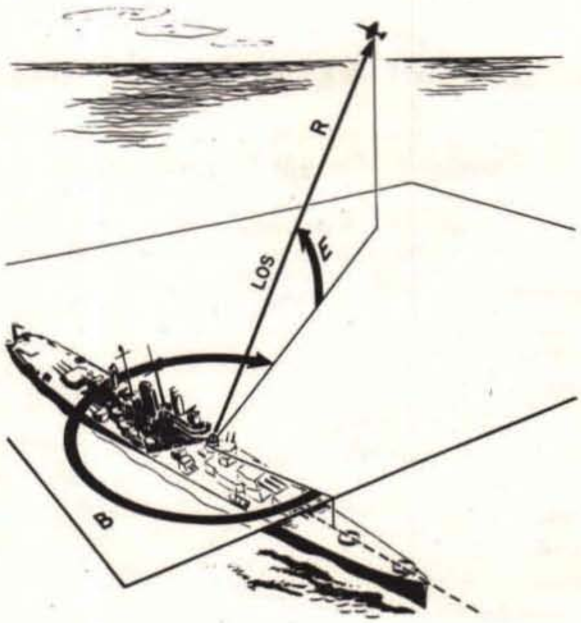

Figure 1.—Target Position in Spherical Coordinates.

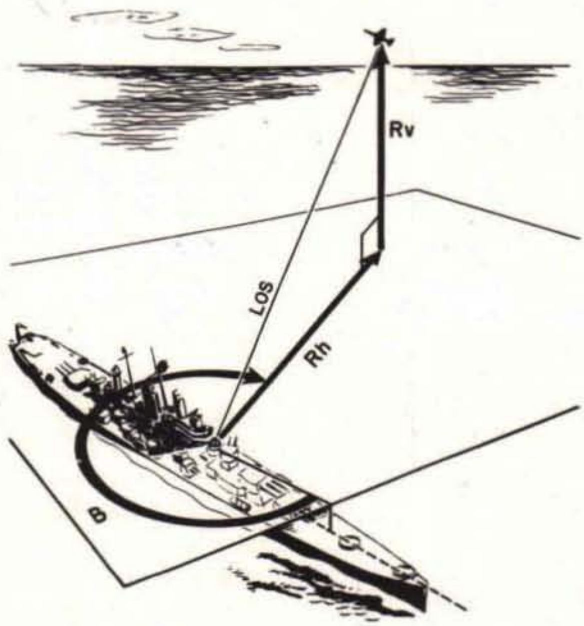

Figure 2.—Target Position in Cylindrical Coordinates.

Chapter 1

PRESENT TARGET POSITION

To determine present target position, the target is located in a reference frame by a system of coordinates. In naval fire control, reference frames originate on own ship; therefore, target position is measured with respect to a point on own ship (reference point).

Reference planes used for the measurements of present target position are:

1. Horizontal plane.
2. Deck plane.

Reference lines used are:

1. Vertical, perpendicular to the horizontal plane.
2. Normal, perpendicular to the deck plane.
3. Own ship centerline.
4. N-S line.

Systems of Coordinates

Systems of coordinates used for measurement are:

1. Spherical Coordinates (figure 1).
   a. Bearing angle.
   b. Elevation angle.
   c. Range along line of sight.
2. Cylindrical Coordinates (figure 2).
   a. Bearing angle.
   b. Vertical (or normal) range component.
   c. Horizontal (or deck) range component.
3. Cartesian Coordinates (figure 3).
   a. Vertical range component.
   b. Horizontal range component in N-S direction.
   c. Horizontal range component in E-W direction.

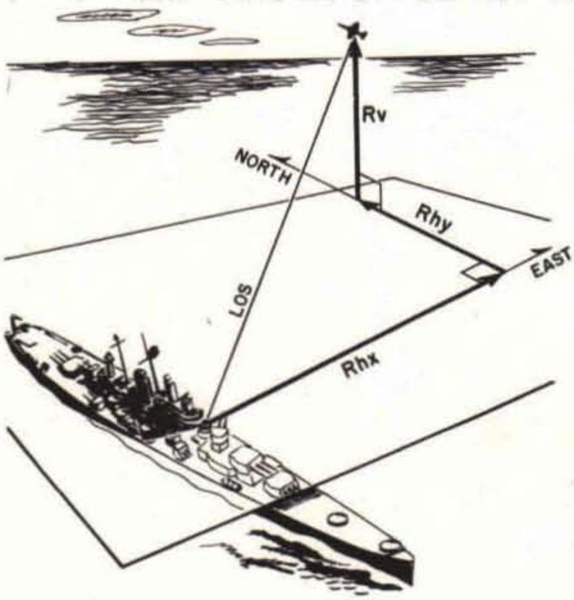

Figure 3.—Target Position in Cartesian Coordinates.

These are the only coordinate systems which are used in present gun fire control systems or considered for use in research studies. The present position of the target in any of these coordinate systems is expressed by three classes of geometrical quantities. That is, Bearings (***B***), Elevations (***E***), and Ranges (***R***).

Target bearings. The class of quantities expressing angular measurements in the horizontal and deck planes is called "bearings." In the expression of present target position, bearing quantities measured in the horizontal plane are called "bearing angles," and bearing quantities measured in the deck plane are called "train angles." When the general term "target bearings" is used in this text, it includes both types of quantities.

Target bearing angles are measured either from own ship centerline or the N-S line. Measurements are made either in the horizontal plane or deck plane to the vertical or normal plane through the line of sight.

The basic bearing quantity (symbolized by basic symbol ***B***) is the angle between the vertical plane through own ship centerline and the vertical plane through the lineof sight measured in the horizontal plane; this quantity is called "relative target bearing." (See figure 4 and table 4A.)

TABLE FOR FIGURE 4

Table 4A

			To vertical plane through LOS	To normal plane through LOS	To normal plane through intersection of horizontal plane and vertical plane through LOS
Target bearing	In horizontal plane	From north-south vertical plane	***By*** 1-6	***By'*** 1-6	***By*** 1-5
		From vertical plane through OS CL	***B*** 3-5	***B'*** 3-6	***B*** 3-5
	In deck plane	From north-south vertical plane	***Bdy*** 13-11	***Bdy'*** 13-8	***Bddy*** 13-10
		From vertical plane through OS CL	***Bd*** 12-11	***Bd'*** 12-8	***Bdd*** 12-10

Positive direction is clockwise viewed from above. Numbers designate the arc measuring the angle.

Table 4B

		In vertical plane through LOS	In normal plane through LOS
Target elevation	From horizontal plane	***E*** 5-14	***E'*** 6-14
	From deck plane	***Ed*** 11-14	***Ed'*** 8-14

Positive direction is upward on target side. Numbers designate the arc measuring the angle.

Table 4C

			And vertical plane through LOS	And normal plane through LOS	And vertical plane through OS CL
Cross level (angle between vertical and normal planes)	About intersection of	Horizontal plane	***Z*** 5	***Z'*** 6	
		Deck plane	***Zd*** 11	***Zd'*** 8	***Zo*** 12

Rotation about line of sight	***Zs*** 14

Direction is positive if clockwise when viewed along axis inward from target. Numbers designate axis about which angle is measured.

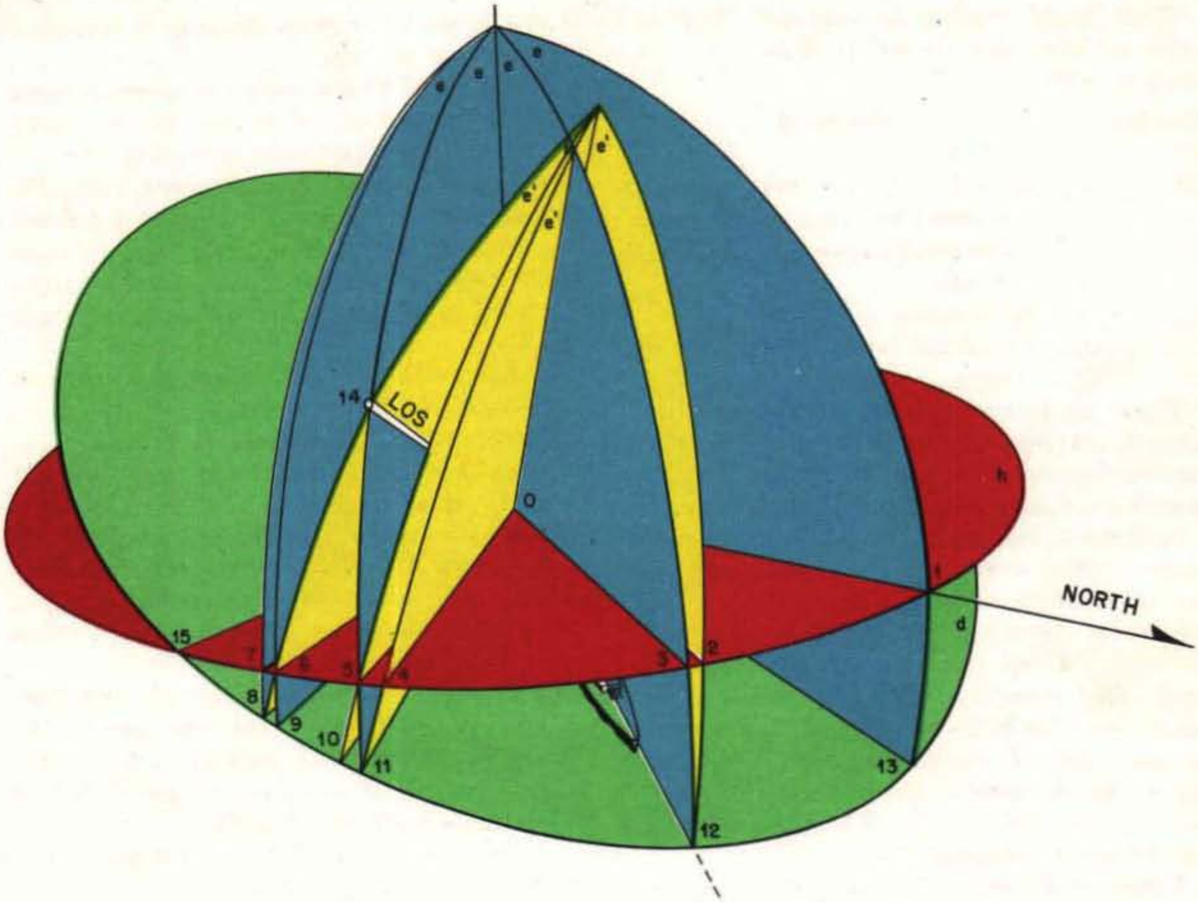

Figure 4.—Angular Target Coordinates and Deck Inclination.

Table 4D

	In vertical plane through LOS	In normal plane through LOS	In vertical plane through OS CL	In normal plane through intersection of horizontal and vertical plane through LOS	In vertical plane normal to intersection of deck and horizontal
Level (angle between horizontal and deck planes)	5–11	6–8	3–12	5–10	About Axis 15
	Ei	***Ei'***	***Eio***	***Eidd***	***Eii***

Positive direction is downward on target side. Numbers designate arc measuring angle.

When target bearing is measured in other ways, modifiers are applied to ***B*** in the order listed as follows:

Modifier	Measured
d	In deck
dd	In deck to normal plane through intersection of horizontal plane and vertical plane through line of sight.
y	From north.
'	To normal plane through line of sight.

When no prime modifier accompanies the symbol, bearing quantity is measured between vertical planes. When no ***d*** is present, bearing quantity is measured in the horizontal plane.

In figure 4, bearing angles expressing present target position in any of the coordinate systems are shown with numerals indicating the arc measuring the angle. In the composite table 4A, each bearing angle is symbolized and defined. For example, in figure 4, bearing of the target from the N-S vertical plane to the vertical plane through the line of sight measured in the horizontal plane is illustrated as the angle 1-5. In composite table 4A, this angle is defined and symbolized ***By***.

Target elevations. The class of quantities expressing angular measurements in vertical and normal planes, is called "elevations."

Target elevation angles are measured in either the vertical or normal plane through the line of sight. Measurements are made to the line of sight either from the horizontal plane or the deck plane.

The basic elevation quantity (symbolized by basic symbol ***E***) is the angle between the horizontal plane and the line of sight, measured in the vertical plane through the line of sight. (See figure 4 and table 4B.)

When target elevation is measured in other ways, modifiers are applied to ***E*** in the order listed as follows:

Modifier	Measured
d	From deck.
'	In normal plane through line of sight.

When no prime modifier accompanies the symbol, elevation quantity is measured in the vertical plane through the line of sight. When no ***d*** is present, elevation quantity is measured from horizontal plane.

In figure 4, elevation angles expressing present target position in any of the coordinate systems are shown with numerals indicating the arc measuring the angle. In composite table 4B, each elevation angle is symbolized and defined. For example, in figure 4, elevation of target above deck plane measured in vertical plane through line of sight is illustrated as the angle 11–14.

In composite table 4B, this angle is defined and symbolized ***Ed***.

Target ranges. The class of quantities expressing linear distances between own ship and target is called "ranges."

The basic range quantity (symbolized by basic symbol ***R***) is the linear distance from own ship to target measured along the line of sight; this quantity is called "present range." (See figure 5 and table 5.)

Components of present range are expressed by applying modifiers to the basic symbol ***R***. These components are separated into three groups—horizontal and deck ranges, N-S and E-W ranges, and target heights.

HORIZONTAL AND DECK RANGES. Basic symbol ***R*** is modified by ***h*** to express the projection of present range in the horizontal plane, forming symbol ***Rh***, and by ***d*** to express projection in deck plane, forming symbol ***Rd***.

NORTH-SOUTH AND EAST-WEST RANGES. Projections of ***R***, ***Rh***, or ***Rd*** are expressed by adding modifier ***y*** for N-S projection, and modifier ***x*** for E-W projection.

TARGET HEIGHTS. Basic symbol ***R*** is modified by ***v*** to express the general quantity indicating vertical range (target height). To express vertical range components, modifiers are applied to ***Rv*** in the order listed as follows:

Modifier	Measured
d	From deck.
'	In plane normal to deck.

When no prime appears, target height is measured in vertical plane; when no ***d*** appears, target height is measured from horizontal plane.

In figure 5, present range and components of present range expressing present target position in any of the coordinate systems are shown with numerals indicating the distances. In

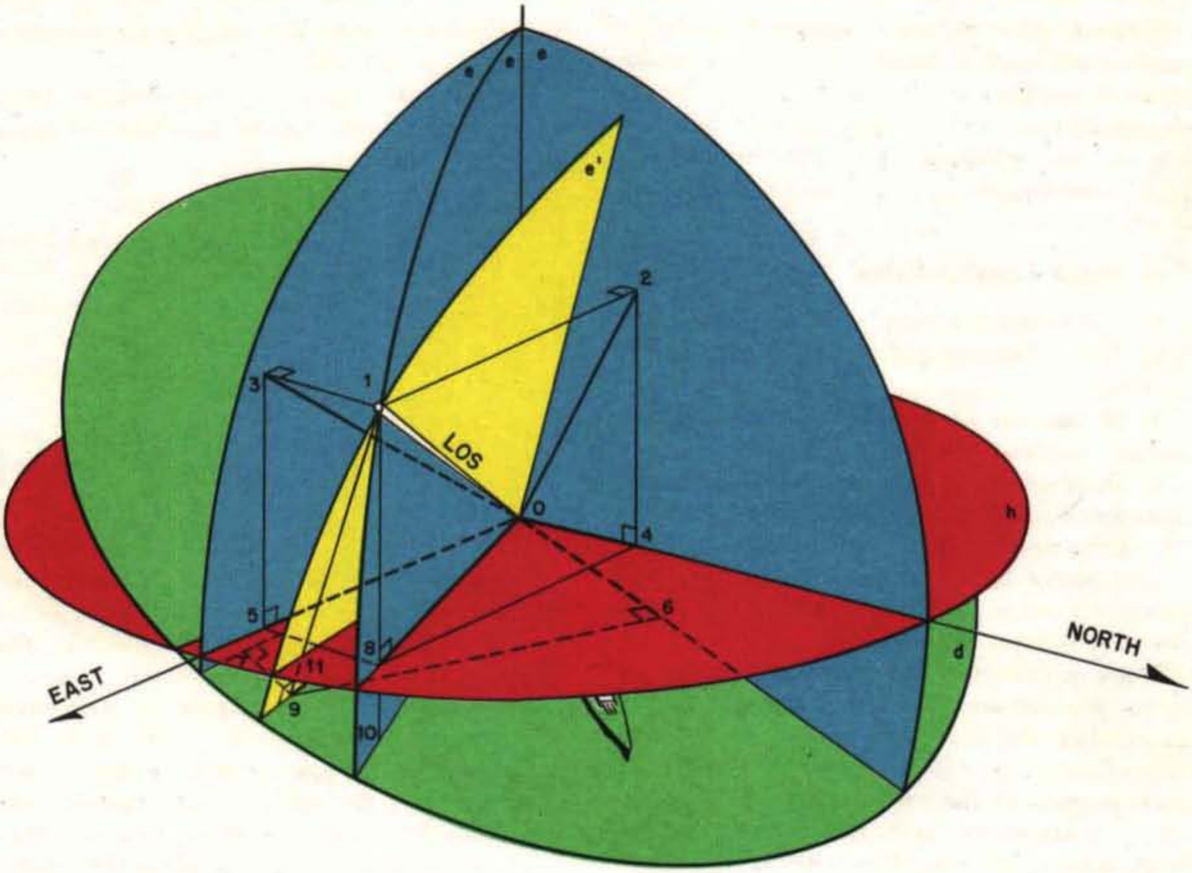

Figure 5.—Target Ranges and Target Heights.

TABLE FOR FIGURE 5

<table>
<tr><td colspan="4"></td><td></td><td>N–S component</td><td>E–W component</td></tr>
<tr><td rowspan="3">Target range</td><td colspan="3">Along LOS</td><td>0-1
R</td><td>0-2
Ry</td><td>0-3
Rx</td></tr>
<tr><td rowspan="2">Along inter-section of</td><td>Vertical plane through LOS</td><td>And horizontal</td><td>0-8
Rh</td><td>0-4
Rhy</td><td>0-5
Rhx</td></tr>
<tr><td>Normal plane through LOS</td><td>And deck</td><td>0-9
Rd</td><td>0-6
Rdy</td><td>0-7
Rdx</td></tr>
</table>

<table>
<tr><td rowspan="4">Target height</td><td rowspan="2">In vertical plane through LOS</td><td>Above horizontal</td><td>*Rv* 8-1</td></tr>
<tr><td>Above deck</td><td>*Rvd* 10-1</td></tr>
<tr><td rowspan="2">In normal plane through LOS</td><td>Above horizontal</td><td>*Rv'* 11-1</td></tr>
<tr><td>Above deck</td><td>*Rvd'* 9-1</td></tr>
</table>

composite table 5, each range quantity is symbolized and defined. For example, in figure 5, the projection of present range in the horizontal plane by a vertical plane through the line of sight is illustrated as the distance 0–8. In composite table 5, this distance is defined and symbolized ***Rh***.

Coordinate Transformation

Geometrical quantities closely associated with target position values are quantities expressing:

1. Inclination of the deck plane from the horizontal plane, and

2. Displacements between reference point and director, and corrections to measured director values accounting for this displacement.

The planes and lines used to express these quantities are essentially the same as those used with target position values.

Deck inclination. Measurements of present target position are made either in stable coordinates where the horizontal is used as the reference plane, or in unstable coordinates where the deck is used as the reference plane. For example, a system of stable spherical coordinates is ***B***, ***E***, and ***R***; the corresponding system of unstable spherical coordinates is ***Bd'***, ***Ed'***, and ***R***. To convert coordinates between these reference systems, the inclination of the deck plane with respect to horizontal plane is measured, and from this data the corrections to be applied to the coordinates are computed.

The rotation of the deck plane with respect to the horizontal plane is measured by two angles related to a specified bearing line:

1. Level angles—where measurement is made in a vertical or a normal plane through a specified bearing line between the horizontal plane and the deck plane, and

2. Cross-level angles—where measurement is made between a vertical and normal plane about an axis in the deck plane or horizontal plane.

Level Angles. The class of quantities expressing angular measurements of deck inclination in vertical or normal planes is called "level."

The basic level quantity (symbolized by basic symbol ***Ei***) is the angle between the horizontal plane and the deck plane measured in the vertical plane through the line of sight. (See figure 4 and table 4D.)

When level angles are measured in other ways, modifiers are applied to ***Ei*** in the order listed as follows:

Modifier	Measured
o	In vertical plane through own ship centerline.
dd	In normal plane, through intersection of horizontal plane and vertical plane through line of sight.
i	In vertical plane perpendicular to intersection of deck and horizontal planes.
'	In normal plane.

In figure 4, all level angles expressing inclination of the deck plane with respect to the horizontal plane are shown with numerals indicating the arc measuring the angle. In composite table 4D, each level angle is symbolized and defined. For example, in figure 4, level angle measured between the horizontal and deck planes in the vertical plane through own ship centerline is illustrated as the angle 3–12. In composite table 4D, this angle is defined and symbolized ***Eio***.

Cross-Level Angles. The class of quantities expressing angular measurements of deck inclination between vertical and normal planes is called "cross-level."

The basic cross-level quantity (symbolized by basic symbol ***Z***) is the angle between the vertical plane through the line of sight and a normal plane, measured about an axis which is the intersection of the horizontal plane and the vertical plane through the line of sight. (See figure 4 and table 4C.)

When cross-level angles are measured in other ways, modifiers are applied to ***Z*** in the order listed as follows:

Modifier	Axis
d	In deck.
o	Along own ship centerline.
s	Along line of sight.
g	Along line of fire or in plane through line of fire.
'	In normal plane.

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In figure 4, all cross-level angles expressing inclination of the deck plane with respect to the horizontal plane are shown with numerals to indicate the axis about which the angle is measured. In composite table 4C, each cross-level angle is symbolized and defined. For example, in figure 4, cross-level angle between the normal plane through the line of sight and a vertical plane measured about an axis which is the intersection of the normal plane through the line of sight and the deck plane is illustrated as the angle measured about axis 8. In composite table 4C, this angle is defined and symbolized ***Zd'***.

Correction Quantities. As stated in the introduction to deck inclination, the correction quantities used in converting between unstable and stable coordinates are computed from the measured values of level and cross-level. These correction quantities are symbolized under "Construction of Symbols for Computational Quantities" in "Symbol System." An example of these correction quantities is the deck tilt correction ***j(Bd)*** used in the Director Mk 37, Computer Mk 1 System, to convert director train ***Bd*** to relative target bearing ***B***.

Static director parallax. In single director systems, the director is usually the parallax reference for the system. In multi-director installations, one of the directors may be the reference, or the reference may be a purely imaginary point that coincides with none of them. In either case, coordinate values and target rates measured by a director in a location other than the reference point require correction for the director's displacement from the point.

The corrections to target rates measured by a displaced director are called "dynamic director parallax corrections," and are discussed in "Dynamic Director Parallax" under "Motion" in this section. The corrections to present target position coordinate values are called "static director parallax corrections," and these are the parallax quantities associated with the measurement of present target position.

The corrections to the coordinate values measured by the displaced director are computed by using as one of the values in the formula a component of the distance between the reference director and the director measuring the target coordinates (director parallax displacement). For example, in computing the correction to director train to refer it to the reference point, the value of the projection of director parallax displacement in the deck plane is required as one of the terms in the formula.

Director Parallax Displacements. The class of quantities expressing linear displacements between the director and reference point is called "director parallax displacements"

The basic director parallax displacement quantity (symbolized by basic symbol ***Ps***) is the linear distance between the director and reference point measured along the director parallax base line. (See figure 6 and table 6.)

Components of director parallax displacement are expressed by applying modifiers to the basic symbol ***Ps***. These components are separated into three groups—horizontal and deck components, N–S and E–W components, and vertical components.

Horizontal and deck components. To express horizontal and deck components of director parallax displacement, modifiers are applied to ***Ps*** in the order listed as follows:

Modifier	Measured
h	In horizontal.
d	In deck.
o	Along own ship centerline.
a	Athwartship, normal to own ship centerline.

Where only modifier ***h*** accompanies the symbol (that is, ***Psh***), the quantity is the projection of ***Ps*** in the horizontal plane; where only modifier ***d*** accompanies the symbol (that is, ***Psd***), the quantity is the projection of ***Ps*** in the deck plane.

Quantities ***Psho*** and ***Psha*** are the components of horizontal projection ***Psh*** along and across the vertical plane through own ship centerline, and quantities ***Psdo*** and ***Psda*** are the components of deck projection ***Psd*** along and across own ship centerline. (See figure 7 and table 7.)

North-south and east-west components. Projections of ***Ps, Psh,*** and ***Psd*** are expressed by adding modifier ***y*** for N–S projection, and ***x*** for E–W projection.

TABLE FOR FIGURE 6

					N–S component	E–W component
Director parallax Displacement	Along base line from reference point to director			*Ps* 0-1	*Psy* 0-2	*Psx* 0-3
	Along intersection of	Vertical plane through base line and	Horizontal	*Psh* 0-8	*Pshy* 0-4	*Pshx* 4-8
		Normal plane through base line and	Deck	*Psd* 0-9	*Psdy* 0-6	*Psdx* 6-9
	In vertical plane through base line		Above horizontal	*Psv* 8-1		
			Above deck	*Psvd* 10-1		
	In normal plane through base line		Above horizontal	*Psv′* 11-1		
			Above deck	*Psvd′* 9-1		

TABLE FOR FIGURE 7

Director parallax Displacement	Along intersection of	Vertical plane through OS CL	And horizontal	*Psho* 0-4
		Normal plane through OS CL	And deck	*Psdo* 0-5
		Vertical plane perpendicular to vertical plane through OS CL	And horizontal	*Psha* 2-4
		Normal plane perpendicular to normal plane through OS CL	And deck	*Psda* 3-5

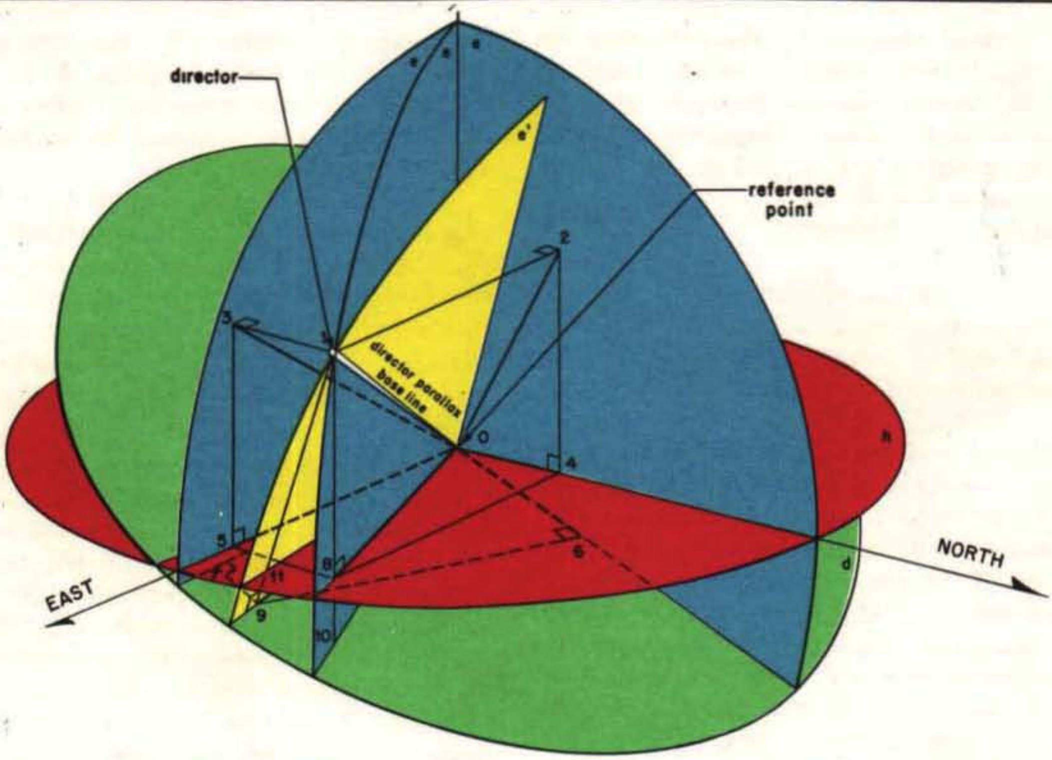

Figure 6.—North-South and East-West Director Parallax Displacements.

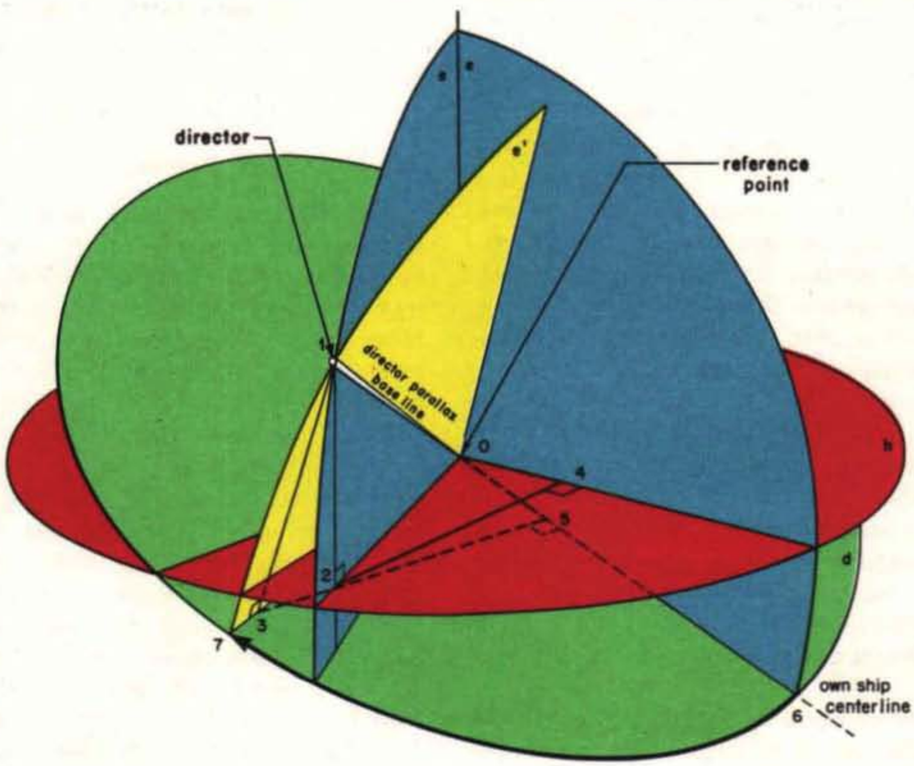

Figure 7.—Director Parallax Displacements.

Vertical components. Basic symbol ***Ps*** is modified by ***v*** to express the general quantity indicating vertical parallax displacement. To express vertical parallax displacement components, modifiers are applied to ***Psv*** in the order listed as follows:

Modifier	Measured
d	From deck.
'	In normal plane.

When no prime appears, vertical component is measured in vertical plane; when no ***d*** appears, vertical component is measured from horizontal plane.

Figures 6 and 7 show all components of director parallax displacement required in computing corrections to target coordinates. Figure 6 shows the horizontal and deck projections, N–S and E–W projections, and the vertical components. Figure 7 shows the components along and across own ship centerline. In composite tables 6 and 7, each director displacement quantity is symbolized and defined. For example, in figure 6, the projection of director parallax displacement in the horizontal plane is illustrated as the distance 0–8. In composite table 6, this distance is defined and symbolized ***Psh.***

Director parallax angle. To express the angle measured in the deck plane about the reference point, between the normal plane through the director parallax base line and own ship centerline, or if reference point is displaced from centerline, the line in deck through reference point parallel to own ship centerline, basic bearing symbol ***B*** is modified by ***o*** and ***s***, forming symbol ***Bos.*** In figure 7, this quantity is illustrated as the angle 6–7.

CORRECTION QUANTITIES. For solution of the antiaircraft fire control problem, it is assumed that the measurements originate at the reference point. As stated in the introduction to "Static Director Parallax," the correction quantities used in converting target coordinate values measured by a displaced director to the reference point are computed by using components of director parallax displacement.

To express the parallax correction to a quantity for measurements made from a director displaced from the reference point, the quantity is enclosed in parentheses and preceded by the quantity modifier $\underline{ps}$. For example, to obtain relative target bearing ***B*** from the reference point, the correction applied to relative target bearing measured by the displaced director is symbolized $\underline{ps}(B)$.

To express a quantity prior to its correction for displacement from the reference point (that is, the quantity including the parallax correction), the quantity is enclosed in parentheses and followed by quantity modifier $\underline{ps}$. For example, relative target bearing as measured by a displaced director is symbolized $(B)\underline{ps}$.

Figures 8 and 9 show all the computed corrections added to the coordinate values measured by a displaced director. Figure 8 shows corrections added to stable target position coordinates, and figure 9 corrections added to unstable target position coordinates. For example, in figure 9, director train value measured by the displaced director (***D***) is symbolized $(Bd')\underline{ps}$. To obtain director train for the reference point (***O***), the correction added to $(Bd')\underline{ps}$ is $\underline{ps}(Bd')$.

Thus $(Bd')\underline{ps}-\underline{ps}(Bd')=Bd'$ means that director train measured by a displaced director minus parallax correction in director train equals director train from the reference point.

Symbolization Problems

This part of the book is established as a reference for target position quantities whose symbolization is made difficult because of the way in which the fire control instrument combines quantities. That is, it is provided to establish and maintain standard symbols for quantities whose symbols may be constructed in more than one way.

One such group of quantities is used in Gun Fire Control System Mk 63 where gun train order is combined with own ship course to obtain true gun train order; that is $Bdg'+Co=Bdgy'$. Since gun train order is measured in the deck plane, and own ship course in the horizontal plane, these quantities can be mathematically combined only by correcting own ship course to deck plane. Therefore, since own ship course should be measured in the deck plane to form a correct summation, it may be symbolized ***Cdo.*** However, since the actual

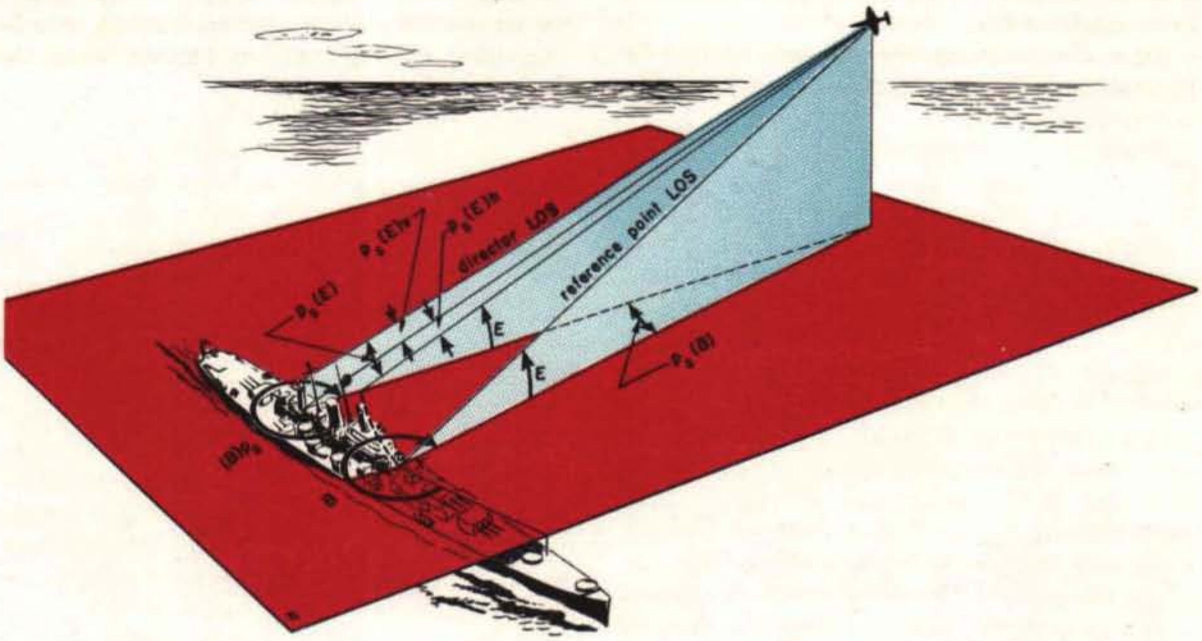

Figure 8.—Director Parallax Corrections to Stable Coordinates.

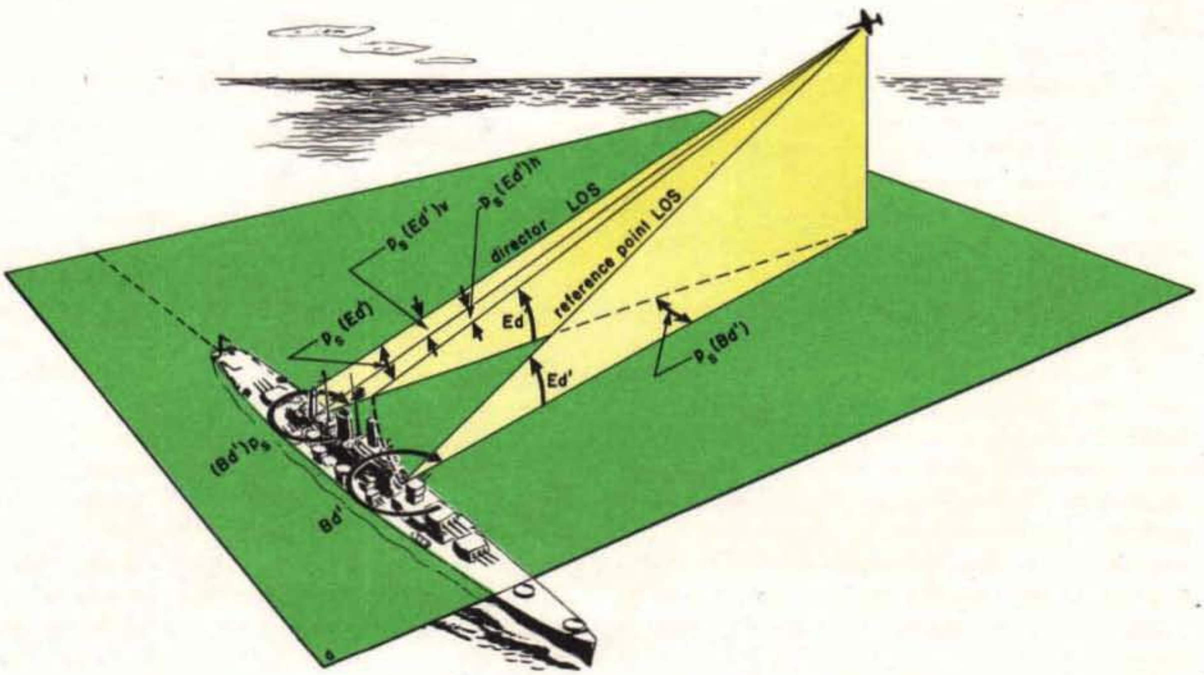

Figure 9.—Director Parallax Corrections to Unstable Coordinates.

value of own ship course used in the addition is measured in the horizontal plane, it may also be symbolized ***Co***.

To avoid confusion, the standard symbol ***Co*** is established for own ship course in this addition. That is, the symbols for this addition are ***Bdg′*** + ***Co*** = ***Bdgy′***. To justify the symbol ***Co*** for own ship course, the summation may be considered to apply at the instant when the deck plane is horizontal.

ANTIAIRCRAFT RELATED QUANTITIES

Chapter 2—Motion

Contents

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Chapter 2

MOTION

Motion quantities are used to compute the traverse and elevation lead angles resulting from relative motion between own ship and target during the time of flight. These lead angles are combined with ballistic correction angles to determine the total traverse and elevation offsets from the line of sight (sight deflection and sight angle).

The motion between own ship and target is expressed in various reference frames. Reference frames used are:

1. Basic inertial frame
2. Earth frame
3. Own ship frame
4. Stabilized frame which moves with own ship motion except for the rate of own ship indicated by the pitometer log.

The measurement of motion in naval gun fire control comprises the expression of:

1. Linear motion of own ship and target
2. Angular motion of the line of sight
3. Motion between frames of reference
4. Courses, headings, and target angles

Linear Motion

The classes of linear motion quantities used in determining lead angles are:

1. Linear displacements during the time of flight, and
2. Linear rates, accelerations, and higher derivatives of motion.

The linear motion quantities are measured about the line of sight in the frame used by the fire control system.

Linear displacements. The class of quantities expressing linear displacements of target and own ship during the time of flight is called "linear displacements."

The types of linear displacements symbolized are those resulting from:

1. Relative motion.
2. Own ship motion.
3. Target motion.

RELATIVE MOTION DISPLACEMENTS. The basic linear displacement quantity (represented by basic symbol ***M***) is the total linear displacement during the time of flight resulting from relative motion between own ship and target in the frame used by the fire control system. (See figure 10 and table 10.)

Components of the basic linear displacement quantity about the line of sight are expressed by applying modifiers to the basic symbol ***M*** to indicate the direction of measurement. Modifiers and their meaning are as follows:

Modifier	Component
b	In horizontal, perpendicular to vertical plane through line of sight.
bd	In deck, perpendicular to normal plane through line of sight.
d	In deck, in normal plane through course line.
e	Perpendicular to line of sight, in vertical plane through line of sight.
e'	Perpendicular to line of sight, in normal plane through line of sight.
h	In horizontal, in vertical plane through course line.
q	In direction of own ship or target heading.
r	In range, along line of sight.
rd	In deck range, in normal plane through line of sight.
rh	In horizontal range, in vertical plane through line of sight.
s	Total, perpendicular to line of sight.
v	In vertical range, in vertical plane through line of sight.
v'	In normal range, in normal plane through line of sight.

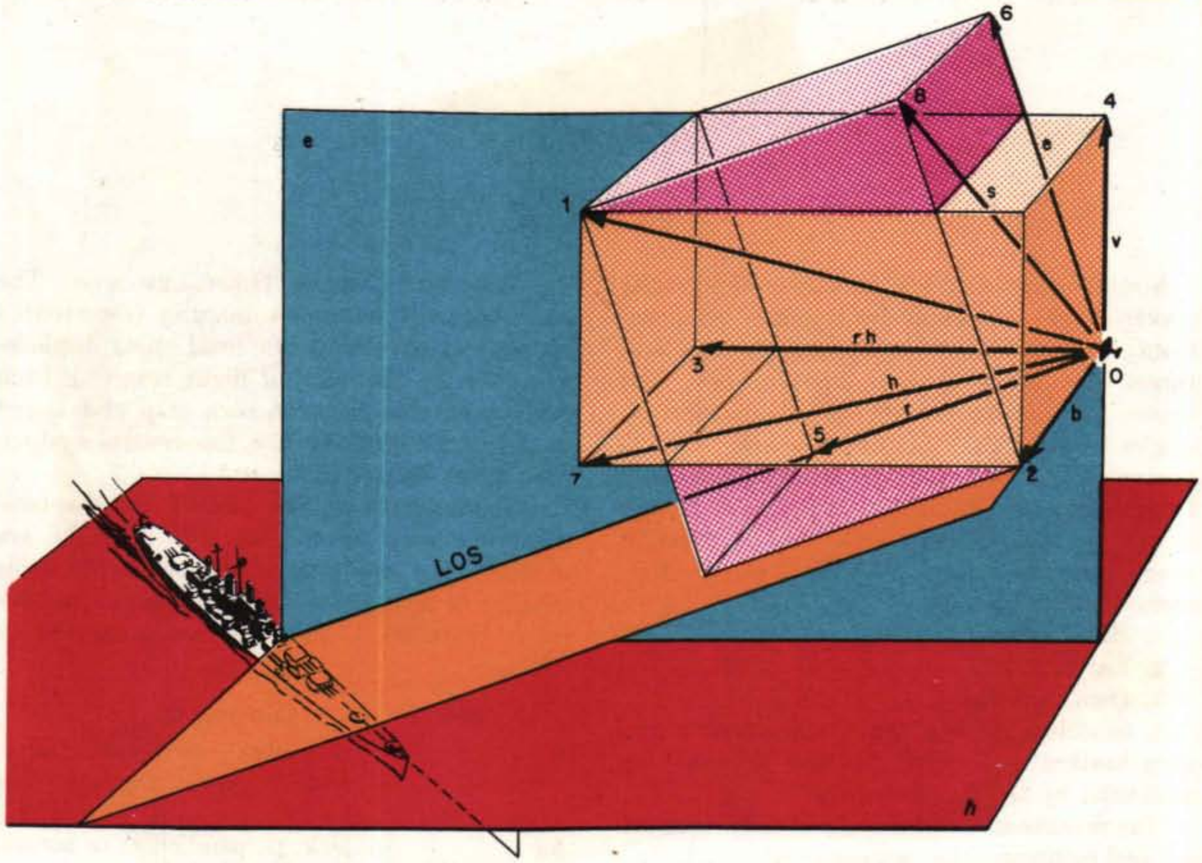

Figure 10.—Target Motion About Line of Sight in Stable Coordinates.

TABLE FOR FIGURE 10

	Relative	Own ship	Target	To advance position	To aiming position
Displacement during time of flight	0–1 ***M***	***Mo***	***Mt***	***M3***	***M4***
Displacement perpendicular to vertical plane through LOS	0–2 ***Mb***	***Mbo***	***Mbt***	***Mb3***	***Mb4***
Displacement in horizontal in vertical plane through LOS	0–3 ***Mrh***	***Mrho***	***Mrht***	***Mrh3***	***Mrh4***
Displacement in vertical plane through LOS	0–4 ***Mv***	***Mvo***	***Mvt***	***Mv3***	***Mv4***
Displacement along LOS	0–5 ***Mr***	***Mro***	***Mrt***	***Mr3***	***Mr4***
Displacement perpendicular to LOS in vertical plane through LOS	0–6 ***Me***	***Meo***	***Met***	***Me3***	***Me4***
Displacement in horizontal in vertical plane through course line	0–7 ***Mh***	***Mho***	***Mht***	***Mh3***	***Mh4***
Total displacement in plane perpendicular to LOS	0–8 ***Ms***	***Mso***	***Mst***	***Ms3***	***Ms4***

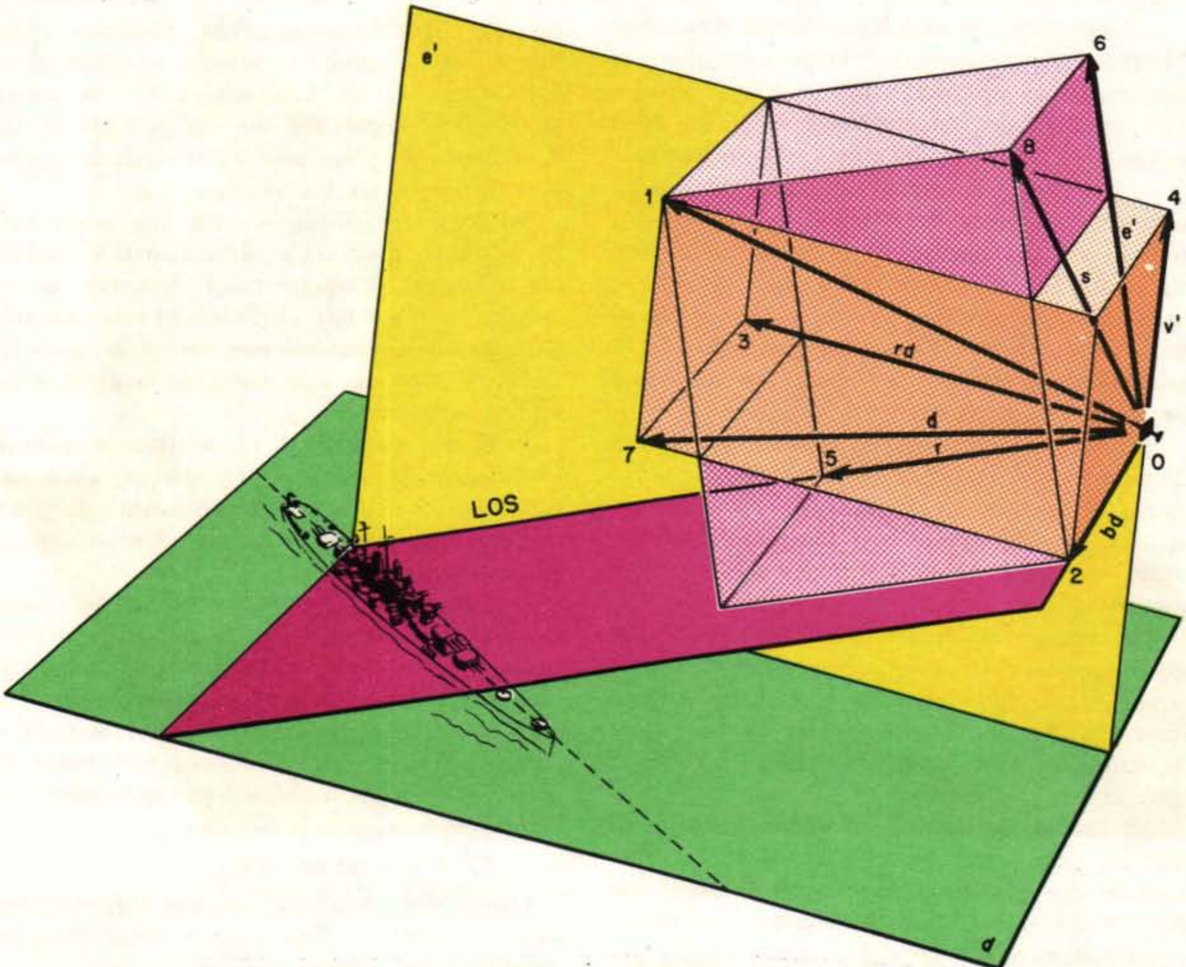

Figure 11.—Target Motion About Line of Sight in Unstable Coordinates.

TABLE FOR FIGURE 11

	Relative	Own ship	Target	To advance position	To aiming position
Displacement during time of flight	***M*** 0–1	***Mo***	***Mt***	***M3***	***M4***
Displacement perpendicular to normal plane through LOS	***Mbd*** 0–2	***Mbdo***	***Mbdt***	***Mbd3***	***Mbd4***
Displacement in deck in normal plane through LOS	***Mrd*** 0–3	***Mrdo***	***Mrdt***	***Mrd3***	***Mrd4***
Displacement along a line normal to deck	***Mv'*** 0–4	***Mvo'***	***Mvt'***	***Mv3'***	***Mv4'***
Displacement along LOS	***Mr*** 0–5	***Mro***	***Mrt***	***Mr3***	***Mr4***
Displacement perpendicular to LOS in normal plane through LOS	***Me'*** 0–6	***Meo'***	***Met'***	***Me3'***	***Me4'***
Displacement in deck in normal plane through LOS	***Md*** 0–7	***Mdo***	***Mdt***	***Md3***	***Md4***

North–South and East–West Relative Motion Displacements. Projections of linear displacements resulting from relative motion are expressed by adding modifier ***y*** for N–S projections, and modifier ***x*** for E–W projections.

Own Ship Motion Displacements. Linear displacements resulting from own ship motion during the time of flight are expressed by terminating the symbol for the same displacement resulting from relative motion with modifier ***o***. Own ship motion is the additional motion imparted to the projectile because the gun moves with the ship.

Target Motion Displacements. Linear displacements resulting from target motion during the time of flight are expressed by terminating the symbol for the same displacement resulting from relative motion with modifier ***t***.

The linear displacement component in any given direction resulting from relative motion is equal to the difference of the corresponding linear displacement components in the same direction resulting from own ship and target motion.

All the linear displacement components resulting from relative, own ship, and target motion are shown in figures 10 through 13. Figure 10 shows the components in stable coordinates, figure 11 the components in unstable coordinates, figure 12 the stable components in the N–S and E–W directions, and figure 13 the unstable components in the N–S and E–W directions.

In composite tables 10 through 13, each linear displacement component is defined and symbolized. For example, in figure 10, the linear displacement measured perpendicular to the vertical plane through the line of sight is illustrated as the distance 0–2. In composite table 10, this linear displacement is defined and symbolized as:

1. ***Mb*** (relative motion).
2. ***Mbo*** (own ship motion).
3. ***Mbt*** (target motion).

Thus, ***Mb=Mbo−Mbt.***

Linear displacements to advance and aiming positions. In some analyses, relative rates between own ship and target are adjusted for the individual effects of ballistic factors as wind, I. V. changes, etc. to obtain the adjusted rates to the advance or aiming positions. The linear displacement components resulting from the integration of these adjusted rates during the time of flight are the components of the total linear displacement to the advance position or to the aiming position.

These linear displacements are symbolized by applying numeral modifiers to the symbols for the same components of displacement resulting from relative motion between own ship and target. Numeral modifier ***3*** is used for advance position, and numeral modifier ***4*** for aiming position.

In figures 10 through 13, all the components of linear displacements to the advance and aiming positions are illustrated since they are in the same directions as the relative motion displacements.

In composite tables 10 through 13, each linear displacement component is defined and symbolized. For example, in figure 10, linear displacement measured perpendicular to the vertical plane through the line of sight is illustrated as the distance 0–2. In composite table 10, this displacement is defined and symbolized as:

1. ***Mb3*** (advance position).
2. ***Mb4*** (aiming position).

Linear rates, accelerations, and higher derivatives of motion. The class of quantities expressing rates of own ship and target is called "linear rates". The rates are symbolized by applying the operator ***D*** to the linear displacement symbol. ***D*** is the symbol for the time rate of change (that is, the differentiating operator d/dt), where the derivative is taken at the instant of firing. Therefore, the rates symbolized by applying the operator ***D*** to the linear displacement symbol are the initial rates measured at the instant of firing.

The types of initial rates symbolized are:

1. Relative rates.
2. Own ship rates.
3. Target rates.

Relative Rates. The basic linear rate quantity (represented by basic symbol ***DM***) is the total relative rate between own ship and target in the frame used by the fire control system.

Components of the basic linear rate quantity are expressed by applying the operator ***D*** to

the symbol for the same component of relative linear displacement.

OWN SHIP RATES. Linear rates of own ship are expressed by applying the operator ***D*** to the symbol for the same component of own ship linear displacement.

TARGET RATES. Linear target rates are expressed by applying the operator ***D*** to the symbol for the same component of target linear displacement.

All the relative rates, own ship rates, and target rates are shown in figures 10 through 13 by the same vectors used to represent their corresponding linear displacements. In composite tables 10 through 13, the rates are defined by replacing "displacement" with "rate." The rates are symbolized by preceding the displacement symbol with operator ***D***. For example, in figure 10, the rate measured perpendicular to the vertical plane through the line of sight is illustrated as the vector 0–2, the same vector used to represent linear displacement in that direction. In composite table 10, this quantity is defined by replacing "displacement" with "rate," and symbolized by preceding the displacement symbol with operator ***D***, as:

1. ***DMb*** (relative rate).
2. ***DMbo*** (own ship rate).
3. ***DMbt*** (target rate).

Integrating a rate over the time of flight gives the linear displacement during the time of flight resulting from that rate. In terms of symbols, this integration involves the removal of the ***D*** operator. For example, integrating range rate ***DMr*** over the time of flight gives linear displacement in range ***Mr***.

If target speed is assumed to be a constant linear rate during the time of flight, this integration merely involves the multiplication of the initial rate by the time of flight. For example, initial range rate times time of flight equals displacement in range, ***DMr***×***T2***=***Mr***. However, when target course or speed vary during the time of flight, the rate averaged over the time of flight will differ from the initial rate. Therefore, to obtain displacement during the time of flight this average rate is multiplied by the time of flight.

AVERAGE RATES. Average relative rates, target rates, and own ship rates are symbolized by applying the numeral modifier ***2*** to the symbol for the initial rate.

All the average rates are shown in figures 10 through 13 by the same vectors used to represent their corresponding linear displacements and initial rates. In composite tables 10 through 13, the average rates are defined by replacing "displacement" with "average rate." The average rates are symbolized by following the symbol for the corresponding initial rates with numeral modifier ***2***. For example, in figure 10, the average rate along the line of sight is illustrated as the vector 0–5, the same vector used to represent linear displacement and initial rate in that direction. In composite table 10, this quantity is defined by replacing "displacement" with "average rate," and symbolized by following the initial rate symbol with numeral modifier ***2*** as:

1. ***DMr2*** (relative rate).
2. ***DMro2*** (own ship rate).
3. ***DMrt2*** (target rate).

When target speed is assumed a constant linear rate during the time of flight initial rates and average rates are equal. In such cases, the symbol for the initial rate is used to represent the quantity.

ADJUSTED RATES. As stated in "Linear displacements to advance and aiming positions," the magnitudes of relative rates are adjusted to compensate for the effects of wind, drift, superelevation, etc. to obtain adjusted rates for prediction to the advance and aiming positions.

Individual corrections to rates. To symbolize the individual corrections to relative rates, the symbol for the rate is enclosed in parentheses and preceded by the appropriate quantity modifier or quantity modifiers. Modifiers for adjusting rates are:

w	Wind.
u	Initial velocity.
b	Ballistics.
p	Gun parallax.
ps	Director parallax.

For example, the correction to range rate ***DMr*** for the effect of wind is ***w(DMr)***, and for the effect of change in initial velocity ***u(DMr)***. The correction to range rate for

TABLE FOR FIGURE 12

		Relative	Own ship	Target	To advance position	To aiming position
Projection of displacement (M) in	N–S vertical plane	[0-2] *My*	*Myo*	*Myt*	*My3*	*My4*
	E–W vertical plane	[0-1] *Mx*	*Mxo*	*Mxt*	*Mx3*	*Mx4*
Projection of displacement (Mh) in	N–S vertical plane	[0-3] *Mhy*	*Mhyo*	*Mhyt*	*Mhy3*	*Mhy4*
	E–W vertical plane	[0-4] *Mhx*	*Mhxo*	*Mhxt*	*Mhx3*	*Mhx4*

TABLE FOR FIGURE 13

		Relative	Own ship	Target	To advance position	To aiming position
Projection of displacement (Md) in	N–S normal plane	[0-1] *Mdy*	*Mdyo*	*Mdyt*	*Mdy3*	*Mdy4*
	E–W normal plane	[0-2] *Mdx*	*Mdxo*	*Mdxt*	*Mdx3*	*Mdx4*

both wind and change in initial velocity is ***wu*(*DMr*)**.

To express rate quantities including the corrections for the individual effects, the rate symbol is enclosed in parentheses and followed by the appropriate quantity modifier or quantity modifiers. For example, range rate ***DMr*** adjusted for wind effect is **(*DMr*)*w***, and for change in initial velocity **(*DMr*)*u***.

Thus, ***DMr*+*w*(*DMr*)=(*DMr*)*w*** means range rate plus corrections to range rate for wind effect equals range rate adjusted for wind.

Adjusted rates to advance and aiming positions. To avoid complex symbols for successive application of modifiers, final adjusted rate used for prediction is symbolized by a numeral modifier denoting the advance or aiming position. Numeral modifier ***3*** is used to denote rates adjusted for all individual effects to the advance position, and numeral modifier ***4*** to denote rates adjusted for all individual effects to the aiming position.

In figures 10 through 13, all the adjusted rates to the advance and aiming positions are

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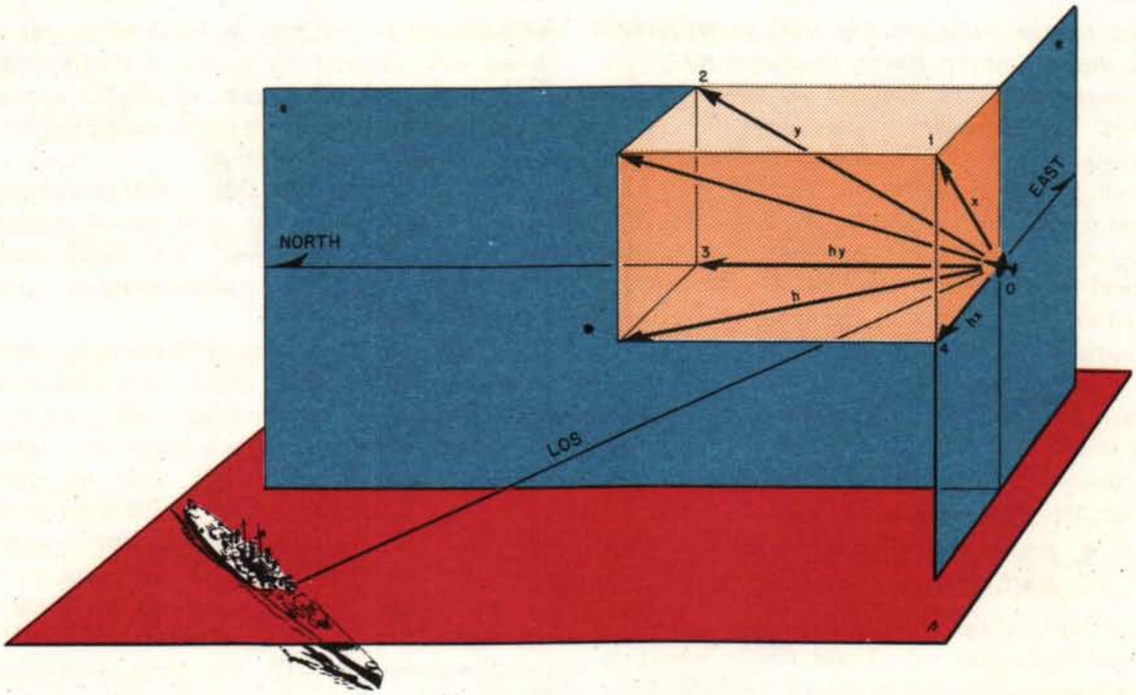

Figure 12.—North-South and East-West Projections of Target Motion in Stable Coordinates.

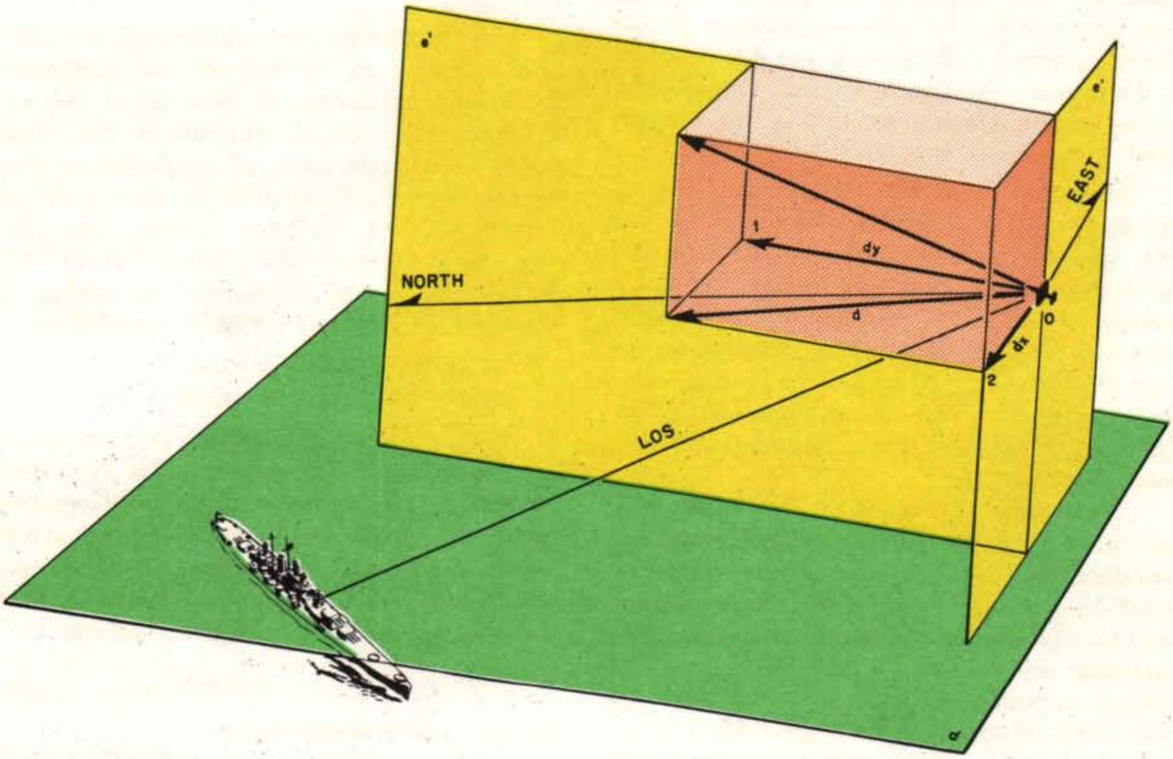

Figure 13.—North-South and East-West Projections of Target Motion in Unstable Coordinates.

shown by the same vectors used to represent their corresponding linear displacements. In composite tables 10 through 13, the rates are defined by replacing "displacement" with "adjusted rate." The rates are symbolized by preceding the displacement symbol with the operator ***D***. For example, in figure 10, the adjusted rate measured perpendicular to the vertical plane through the line of sight is illustrated as the vector 0–2, the same vector used to represent linear displacement in that direction. In composite table 10, this quantity is defined by replacing "displacement" with "adjusted rate," and symbolized by preceding the symbols for displacement to advance and aiming positions with operator ***D***, as:

1. ***DMb3*** (advance position).
2. ***DMb4*** (aiming position).

Integrating an adjusted rate over the time of flight gives the linear displacement to the advance or aiming positions resulting from that rate. In terms of symbols, this integration merely involves the removal of the ***D*** operator. For example, integrating bearing rate adjusted to the advance position ***DMb3*** over the time of flight gives linear displacement to the advance position measured perpendicular to the vertical plane through the line of sight ***Mb3***. (See figure 10.)

Dynamic Director Parallax. The director measuring the rates of motion between own ship and target usually is the reference point for the system. However, in multi-director installations, one director may be the reference for the system, and rates measured from the other directors require correction to the reference director or reference point. These corrections are called "dynamic director parallax corrections."

To express the parallax correction to a rate quantity measured from a displaced director, the rate is enclosed in parentheses and preceded by quantity modifier ***ps***. For example, to obtain total rate of relative motion between own ship and target for the reference point ***DM***, the correction applied to the rate measured from the displaced director is ***ps***(***DM***).

To express a rate quantity prior to its correction for displacement from the reference point (that is, the quantity including the parallax correction), the rate is enclosed in parentheses and followed by quantity modifier ***ps***. For example, the total rate of relative motion between own ship and target as measured by a displaced director is (***DM***)***ps***.

Thus, (***DM***)***ps***−***ps***(***DM***)=***DM*** means total relative rate measured by a displaced director minus parallax correction for displacement from reference point equals total relative rate from the reference point.

Higher Derivatives of Linear Motion. When target course or speed vary during the time of flight, higher order derivatives are used to compute average target rates and target path curvature during the time of flight. Higher order derivatives are symbolized in the same manner as initial rates except a superscript numeral is applied to the ***D*** operator preceding the rate symbol to indicate the order of the derivative, as D^2 for second derivative (acceleration) and D^3 for third derivative. Higher order derivatives of linear motion are illustrated in figures 10 through 13 as they are in the same direction as their corresponding linear rates.

In composite tables 10 through 13, higher order derivatives are defined and symbolized by adding a superscript numeral to the rate symbol. For example, in figure 10, the second derivative (acceleration) of range displacement along the line of sight is illustrated as the vector 0-5. In composite table 10, this quantity is defined by replacing "displacement" with "acceleration" and symbolized by adding the superscript numeral ***2*** to the ***D*** operator as:

1. D^2Mr (relative motion).
2. D^2Mro (own ship motion).
3. D^2Mrt (target motion).

Frames of Reference. To distinguish between frames to which linear displacements, rates, and higher derivatives of motion are referred, the quantity is enclosed in parentheses and followed by a quantity modifier to indicate the frame. Quantity modifiers used are:

Modifier	Referred to—
s	Inertial space.
k	Earth.
o	Frame rigidly attached to own ship.

A quantity not thus modified is referred to the stabilized frame moving with own ship rates except for the rate of own ship as indicated by the pitometer log. For example, to express range rate in the inertial frame, ***DMr*** is enclosed in parentheses and followed by quantity modifier ***s***, forming symbol (***DMr***)***s***, and to express target speed in the earth frame ***DMt*** is modified by ***k*** forming symbol (***DMt***)***k***.

These rules for using reference frame modifiers are applied only where there is possibility of confusion regarding the frames to which quantities are referred. If an entire discussion concerns one frame, modifiers may be omitted.

Angular Motion

The classes of angular motion quantities used in determining lead angles are:

1. Relative angular displacements of the line of sight during the time of flight, and

2. Relative angular rates, accelerations, and higher derivatives of motion of the line of sight.

The relative angular motions of the line of sight are measured with respect to lines fixed in the reference frame used by the fire control system.

Angular displacements. The class of quantities expressing relative angular displacements of the line of sight during the time of flight measured in traverse planes is called "lateral displacements".

The class of quantities expressing relative angular displacements of the line of sight during the time of flight measured in elevation planes is called "elevation displacements".

LATERAL DISPLACEMENTS. The basic lateral displacement quantity (represented by basic symbol ***S***) is the total relative angular displacement between the line of sight and the line to the future target position.

Portions of this total displacement angle measured in traverse planes (lateral displacements) are symbolized by applying modifiers to basic symbol ***S*** to indicate the plane in which the lateral displacement is measured. When the first modifier is ***s*** or ***g***, plane of measurement is a slant plane:

Through director elevation axis.......... ***s***
Through gun elevation axis............. ***g***

When no further modifiers appear, the slant plane passes through the line of sight, and the elevation axis is stabilized to the horizontal plane.

Other letters appearing after the ***s*** or ***g*** have the following meaning:

d.... Elevation axis is unstabilized and lies in deck plane.
2.... Slant plane passes through the line to the future target position.

Lateral displacements are further modified to indicate the planes from (and to) which the displacements are measured. To indicate the plane to which the displacement is measured, lateral displacement symbol is followed by ′ (prime) for a plane normal to the deck plane; to indicate the plane from which the offset is measured, lateral displacement symbol is preceded by ′ (prime) for a plane normal to the deck plane. When no prime modifiers appear, lateral displacements are measured between vertical planes.

ELEVATION DISPLACEMENTS. The basic elevation displacement quantity (represented by basic symbol ***A***) is the difference in elevation from the horizontal plane between the line of sight and the line to the future target position, measured upward to the future target position in a vertical plane.

Elevation displacements, made in combination with lateral displacements, are symbolized by using the basic elevation displacement symbol ***A***, modified by the designation for the traverse plane from (or to) which the measurement is made.

Elevation displacement angles are further modified to indicate the elevation plane in which the displacement is measured. Elevation displacements are followed by ′ (prime) to indicate measurement in a plane normal to deck plane. When no ′ (prime) appears, elevation displacement is measured in a vertical plane.

Figure 14 shows all the values of lateral and elevation displacements with numerals to indicate the arc measuring each displacement angle. In composite table 14 each lateral and elevation displacement is defined and symbolized. For example, the lateral displacement measured from the line of sight to the vertical plane through the line to the future target position in the slant plane through the line of sight and through the director elevation axis in the hori-

TABLE FOR FIGURE 14

				In vertical plane through future LOS	In normal plane through future LOS
Elevation angular displacement	From future LOS to slant plane through present LOS and	Through director elevation axis in	Horizontal	***As*** 10-2	***As'*** 10-3
			Deck	***Asd*** 10-4	***Asd'*** 10-5
		Through gun elevation axis in	Horizontal	***Ag*** 10-6	***Ag'*** 10-7
			Deck	***Agd*** 10-8	***Agd'*** 10-9
				In vertical plane through present LOS	In normal plane through present LOS
	From present LOS to slant plane through future LOS and	Through director elevation axis in	Horizontal	***As2*** 1-11	***As2'*** 1-12
			Deck	***Asd2*** 1-13	***Asd2'*** 1-14
		Through gun elevation axis in	Horizontal	***Ag2*** 1-15	***Ag2'*** 1-16
			Deck	***Agd2*** 1-17	***Agd2'*** 1-18
				To vertical plane through future LOS	To normal plane through future LOS
Traverse angular displacement	From present LOS in slant plane through present LOS and through	Director elevation axis in the	Horizontal	***Ss*** 1-2	***Ss'*** 1-3
			Deck	***Ssd*** 1-4	***Ssd'*** 1-5
		Gun elevation axis in the	Horizontal	***Sg*** 1-6	***Sg'*** 1-7
			Deck	***Sgd*** 1-8	***Sgd'*** 1-9
				From vertical plane through LOS	From normal plane through LOS
	To future LOS in slant plane through future LOS and through	Director elevation axis in the	Horizontal	***Ss2*** 11-10	***'Ss2*** 12-10
			Deck	***Ssd2*** 13-10	***'Ssd2*** 14-10
		Gun elevation axis in the	Horizontal	***Sg2*** 15-10	***'Sg2*** 16-10
			Deck	***Sgd2*** 17-10	***'Sgd2*** 18-10
				From vertical plane through present LOS	From normal plane through present LOS
Horizontal and deck angular displacement	In horizontal plane	To vertical plane through future LOS		***Sh*** 19-21	***'Sh*** 20-21
		To normal plane through future LOS		***Sh'*** 19-26	***'Sh'*** 20-26
				From vertical plane through present LOS	From normal plane through present LOS
	In deck plane	To vertical plane through future LOS		***Sd*** 23-25	***'Sd*** 24-25
		To normal plane through future LOS		***Sd'*** 23-22	***'Sd'*** 24-22

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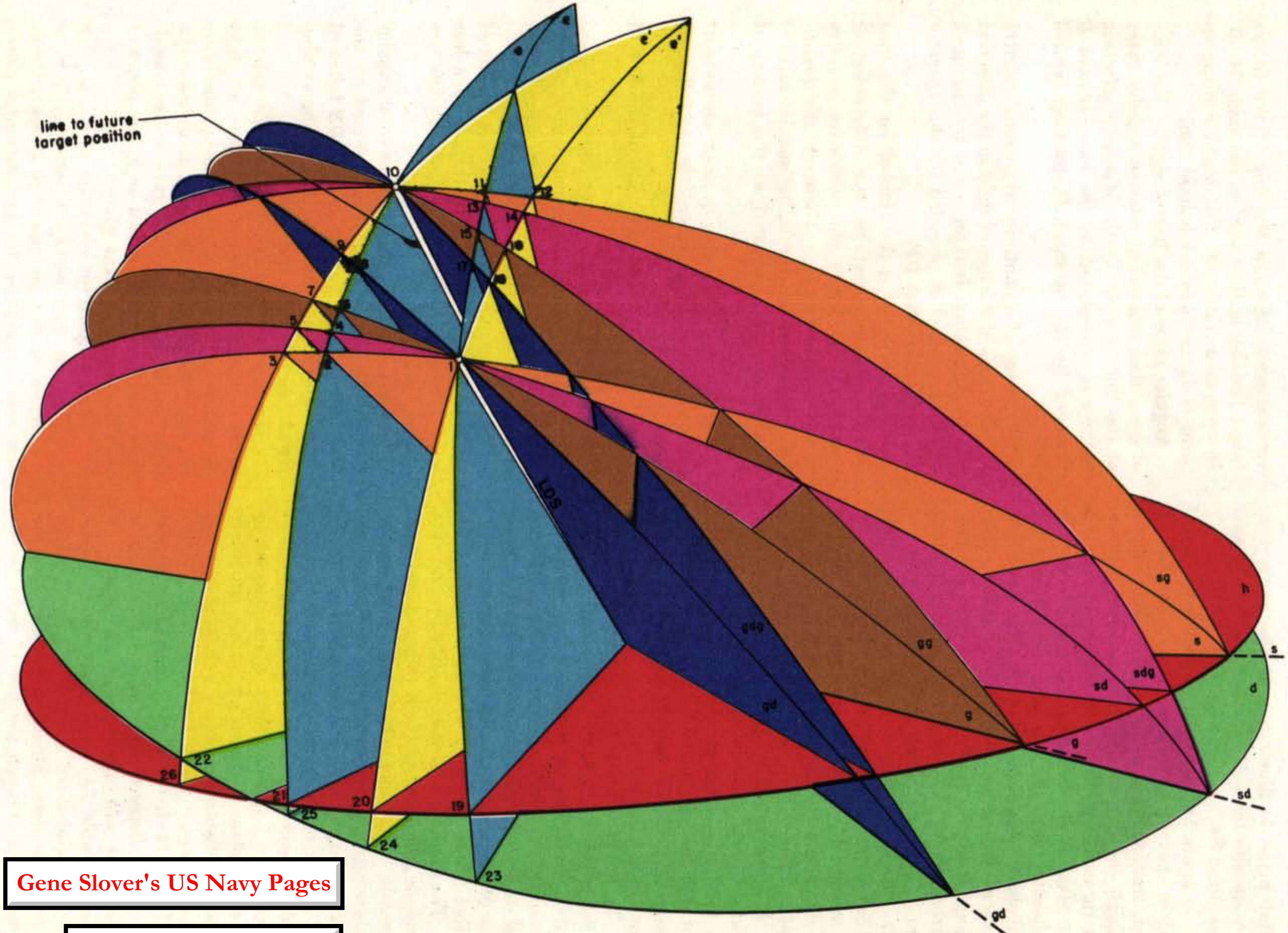

Figure 14.—Traverse and Elevation Angular Displacements.

zontal plane is illustrated as the angle 1–2. In composite table 14, this angle is defined and symbolized ***Ss***.

In figure 14, elevation displacement measured in the vertical plane through the line of sight, from the line of sight to the slant plane through the line to the future target position and through the director elevation axis in the deck plane is illustrated as the angle 1–13. In composite table 14, this angle is defined and symbolized ***Asd2***. As stated, this elevation displacement is measured to the slant plane through the line to the future target position and through the director elevation axis in the deck plane. The designation for this slant plane is ***sd2***. Since elevation displacements are modified to indicate the plane from (or to) which they are measured, the designation ***sd2*** for the slant plane is applied to the basic elevation displacement symbol.

HORIZONTAL AND DECK DISPLACEMENTS. Besides lateral displacements in slant planes, the total displacements between the line of sight and the line to the future target position measured in the horizontal plane or in the deck plane are symbolized.

To indicate total displacements measured in the horizontal plane (horizontal displacements), basic lateral displacement symbol ***S*** is modified by ***h*** forming symbol ***Sh;*** to indicate total displacements measured in the deck plane (deck displacements), basic lateral displacements symbol ***S*** is modified by ***d,*** forming symbol ***Sd***.

The angles are further modified to indicate the plane from (or to) which the measurements are made. To indicate the plane to which the displacement is measured, the symbol is followed by ′ (prime) for a plane normal to the deck plane; to indicate the plane from which the displacement is measured, the symbol is preceded by ′ (prime) for a plane normal to the deck plane. When no prime modifiers appear, the displacements are measured between vertical planes.

Figure 14 shows all the values of horizontal and deck displacements with numerals to indicate the arc measuring each angle. In composite table 14, each displacement is defined and symbolized. For example, displacement in the deck plane, measured from the normal plane through the line of sight to the vertical plane through the line to the future target position is illustrated as the angle 24–25. In composite table 14, this angular displacement is defined and symbolized ***′Sd***.

Angular rates of the line of sight. The class of quantities expressing relative angular rates of the line of sight in the direction affecting bearing is represented by the basic symbol ***B*** preceded by the operator ***D,*** forming symbol ***DB***.

The class of quantities expressing relative angular rates of the line of sight in the direction affecting elevation is represented by the basic elevation symbol ***E*** preceded by the operator ***D,*** forming symbol ***DE***.

The operator ***D*** is the symbol for the time rate of change (that is, the differentiating operator d/dt) where the derivative is taken at the instant of firing. Therefore, the quantities symbolized are the initial angular rates of the line of sight measured at the instant of firing.

Angular rates of motion in naval antiaircraft fire control can be considered in the following categories:

1. Total relative angular rate of the line of sight.
2. Relative angular rates in traverse planes.
3. Relative angular rates in elevation planes.
4. Relative angular rate of the line of sight in the horizontal and deck planes.

All the angular rate quantities are measured at the instant of firing with respect to a line fixed in the reference frame used by the fire control system.

TOTAL ANGULAR RATE. The total angular rate of the line of sight is represented by the basic angular bearing rate symbol ***DB*** followed by modifiers ***s*** and numeral ***2,*** forming symbol ***DBs2*** (see figure 15 and table 15).

TRAVERSE ANGULAR RATES. To express relative angular rates of the line of sight measured in traverse planes, basic angular bearing rate symbol ***DB*** is modified to indicate the slant plane in which the rate is measured. When the first modifier is ***s*** or ***g,*** the plane of measurement is a slant plane:

Through director elevation axis--------***s***
Through gun elevation axis----------***g***

When no further modifiers appear, elevation axis is stabilized to the horizontal plane.

When modifier ***d*** appears after the ***s*** or ***g***, the elevation axis is unstabilized and lies in the deck plane.

Figure 15 shows the total angular rate of the line of sight, and the angular rates in the traverse planes with numerals to indicate each rate. In composite table 15, each traverse angular rate is defined and symbolized. For example, in figure 15, the angular rate of the line of sight in the slant plane through the director elevation axis in the deck plane is illustrated as the rate 1–4. In composite table 15, this angular rate is defined and symbolized ***DBsd***.

Frames of reference. The total angular rate and the traverse rates of the line of sight are measured with respect to the initial position of the line of sight (that is, the position of the line of sight at the instant of firing). This initial position is fixed in the reference frame used by the fire control system to measure the angular rates. To denote the reference frame in which the initial position of the line of sight is fixed, the angular rate symbol is enclosed in parentheses and followed by a quantity modifier to indicate the frame. Quantity modifiers used are:

Modifier	Frame
s	Inertial frame
k	Earth
e	Frame rigidly attached to own ship.

For example, traverse angular rate ***DBs*** measured with respect to the initial position of the line of sight fixed in the earth frame is symbolized (***DBs***)***k***, and total angular rate ***DBs2*** measured with respect to the initial position of the line of sight fixed in the inertial frame is symbolized (***DBs2***)***s***.

These rules for using reference frame modifiers are applied only where there is possibility of confusion regarding the frames to which quantities are referred. If an entire discussion concerns one frame, modifiers may be omitted.

Elevation Angular Rates. The class of quantities expressing relative angular rates of the line of sight measured in elevation planes is called "elevation angular rates."

The basic quantity (represented by basic symbod ***DE***) is the angular rate of the line of sight measured in the vertical plane through the line of sight with respect to the intersection of the vertical plane through the line of sight and the horizontal plane. (See figure 16 and table 16.) This quantity expresses the time rate of change of target elevation.

When angular elevation rates are measured in other ways, modifiers are applied to ***DE*** in the order listed as follows:

Modifier	Measured
d	With respect to an intersection in the deck plane.
′	In normal plane.

When no prime modifier appears, elevation angular rate is measured in the vertical plane through the line of sight. When no ***d*** is present, elevation angular rate is measured with respect to an intersection in the horizontal plane.

Figure 16 shows all the angular rates of the line of sight measured in elevation planes with numerals to indicate each rate. In composite table 16, each elevation angular rate is defined and symbolized. For example, the angular elevation rate in the normal plane through the line of sight measured with respect to the intersection of the normal plane through the line of sight and the deck plane is illustrated as the vector 3–5. In composite table 16, this rate is defined and symbolized ***DEd′***.

In figure 16, angular elevation rates ***DE*** and ***DEd***, and the angular elevation rates ***DE′*** and ***DEd′*** are represented by a single vector since they are measured in the same elevation planes. However, their magnitudes differ because they are measured with respect to different intersecting lines.

Frames of reference. The angular elevation rates of the line of sight are measured with respect to a line fixed in the reference frame used by the fire control system.

The location of the reference frame in which the reference line is fixed is indicated by the elevation rate symbol itself in the case of own ship and the earth frame, therefore, no additional modifier is required. That is, angular elevation rates ***DE*** and ***DE′*** are measured with respect to the intersection of an elevation plane with the horizontal plane, therefore, are measured with respect to a line fixed in the earth frame. Angular elevation rates ***DEd***

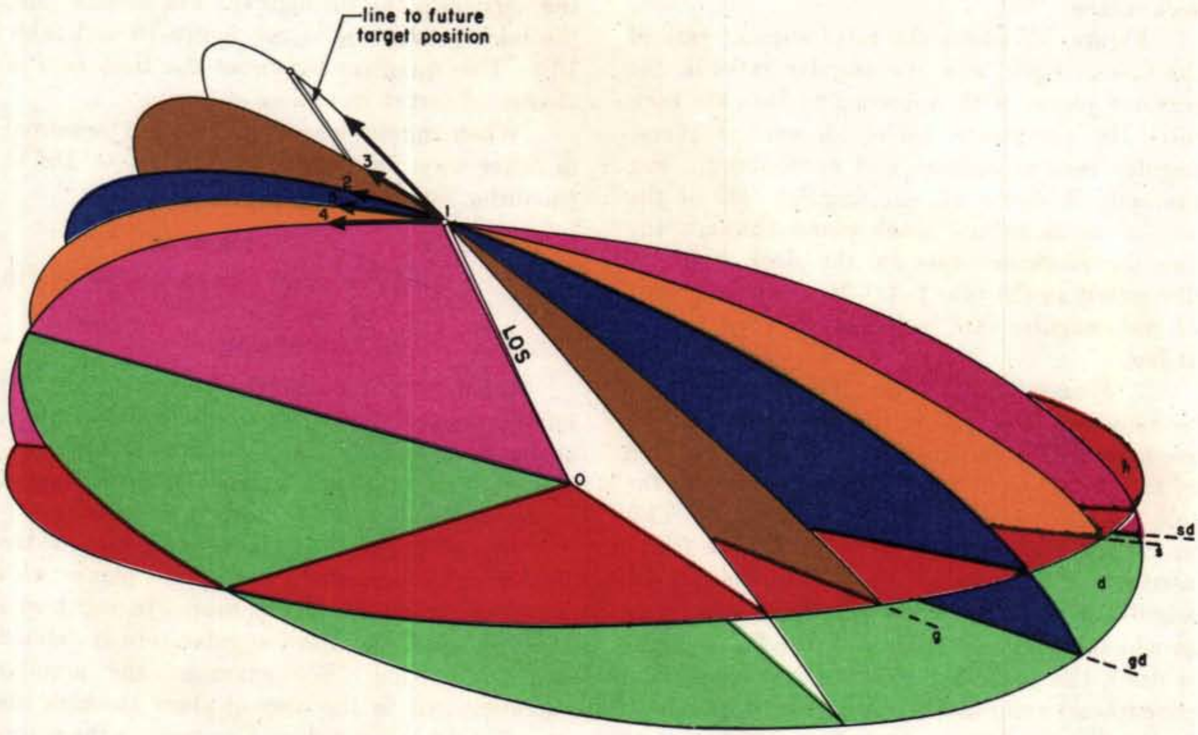

Figure 15.—Total Angular Rate and Traverse Angular Rates of the Line of Sight.

TABLE FOR FIGURE 15

Angular rate of the line of sight, measured with respect to the initial position of the line fixed in the frame used by the fire control system	In the slant plane through the director elevation axis in	The horizontal	**DBs** 1-5
	In the slant plane through the director elevation axis in	The deck	**DBsd** 1-4
	In the slant plane through the gun elevation axis in	The horizontal	**DBg** 1-3
	In the slant plane through the gun elevation axis in	The deck	**DBgd** 1-2

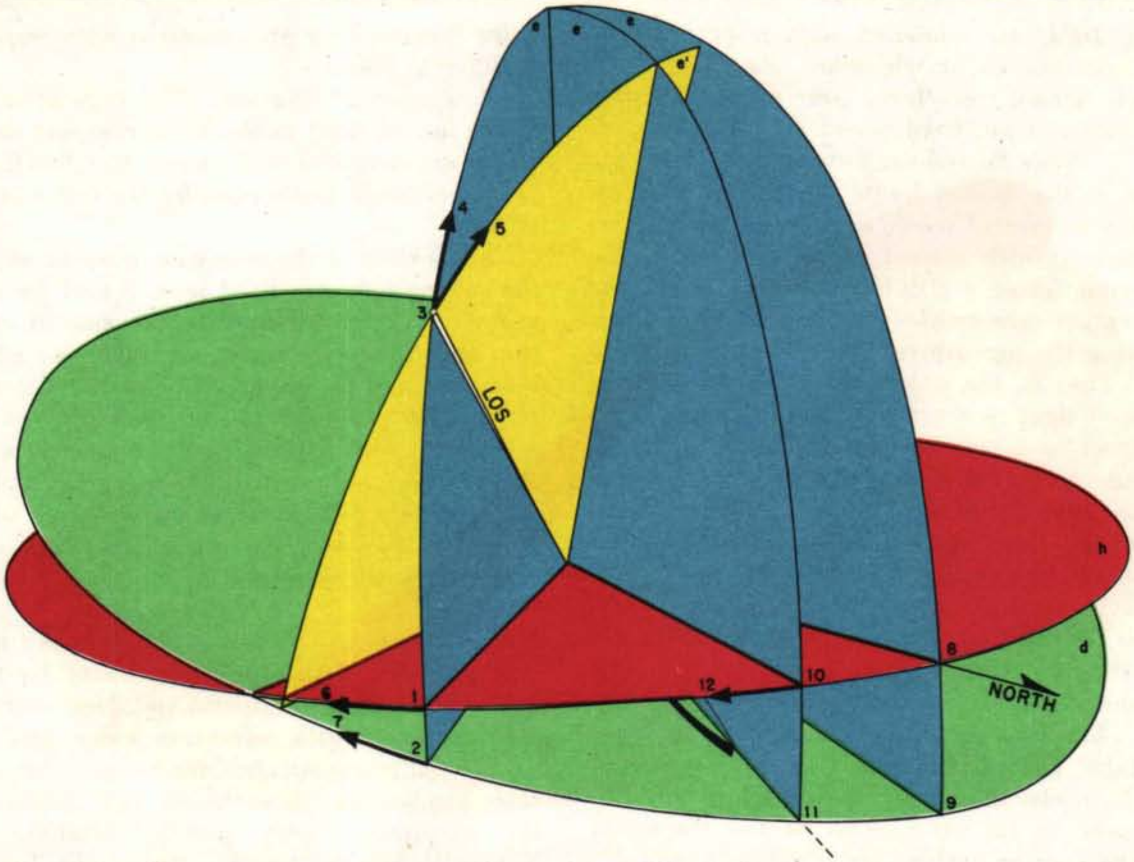

Figure 16.—Elevation Angular Rates and Horizontal and Deck Angular Rates of the Line of Sight.

TABLE FOR FIGURE 16

Angular rate of the line of sight, measured with respect to the	N–S line	In horizontal plane	***DBy*** 1–6
	Intersection of N–S vertical plane and deck	In deck plane	***DBdy*** 2–7
	Intersection of horizontal and vertical plane through OS CL	In horizontal plane	***DB*** 1–6
	OS CL	In deck plane	***DBd*** 2–7
	Intersection of horizontal and vertical plane through OS CL	In vertical plane	***DE*** 3–4
	Intersection of horizontal and normal plane through LOS	In normal plane	***DE'*** 3–5
	Intersection of deck and vertical plane through LOS	In vertical plane	***DEd*** 3–4
	Intersection of deck and normal plane through LOS	In normal	***DEd'*** 3–5
Angular rate of own ship speed vector, measured with respect to	N–S line	In horizontal plane	***DCo*** 10–12

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and ***DEd'*** are measured with respect to the intersection of an elevation plane with the deck plane, therefore, are measured with respect to a line fixed in own ship frame.

Since no angular measurement reference line in the inertial frame can be indicated by the rate symbol itself, angular elevation rates measured with respect to a line fixed in the inertial frame are obtained by enclosing the elevation rate symbol in parentheses and following the parentheses with quantity modifier ***s***. That is, the angular elevation rate of the line of sight in a vertical plane measured with respect to a line fixed in the inertial frame is symbolized (***DE***)***s***, and the angular elevation rate of the line of sight in a normal plane measured with respect to a line fixed in the inertial frame is symbolized (***DE'***)***s***.

HORIZONTAL AND DECK ANGULAR RATES. The class of quantities expressing angular rates of the line of sight in the horizontal and deck planes is called "bearing rates."

The basic quantity (represented by basic symbol ***DB***) is the angular rate of the line of sight measured in the horizontal plane with respect to the intersection of the horizontal plane and the vertical plane through own ship centerline. (See figure 16 and table 16.) This quantity expresses the time rate of change of relative target bearing.

When measured in other ways, modifiers are applied to ***DB*** in the order listed as follows:

Modifier	Measured
d	In the deck plane.
y	With respect to N-S line.

Figure 16 shows all the angular rates of the line of sight measured in the horizontal and deck planes with numerals to indicate each rate. In composite table 16, each horizontal and deck rate is defined and symbolized. For example, the angular rate of the line of sight in the deck plane measured with respect to own ship centerline is illustrated as the vector 2–7. In composite table 16, this rate is defined and symbolized ***DBd***. This quantity expresses the time rate of change of relative director train.

In figure 16, angular rates ***DB*** and ***DBy***, and angular rates ***DBd*** and ***DBdy*** are represented by a single vector since they are measured in the same planes. However, their magnitudes differ because they are measured with respect to different lines.

Frames of reference. The angular rates of the line of sight in the horizontal and deck planes are measured with respect to a line fixed in the reference frame used by the fire control system.

The location of the reference frame in which the reference line is fixed is indicated by the angular rate symbol itself in the case of own ship and the earth frame; therefore, no additional modifier is required. That is, angular rates ***DBy*** and ***DBdy*** are measured with respect to north; therefore, are measured with respect to a line fixed in the earth frame. Angular rates ***DB*** and ***DBd*** are measured with respect to own ship centerline; therefore, are measured with respect to a line fixed in own ship frame.

Since no angular measurement reference line in the inertial frame can be indicated by the rate symbol itself, horizontal and deck angular rates measured with respect to a line fixed in the inertial frame are obtained by enclosing the rate symbol in parentheses and following the parentheses with quantity modifier ***s***. That is, horizontal angular rate of the line of sight measured with respect to a line fixed in the inertial frame is symbolized (***DB***)***s***, and deck angular rate of the line of sight measured with respect to a line fixed in the inertial frame is symbolized (***DBd***)***s***.

Angular rate of own ship speed vector. The angular rate of own ship horizontal speed vector measured with respect to the N–S line is expressed by preceding the symbol for own ship course ***Co*** with the operator ***D***, forming symbol ***DCo***. (See figure 16 and table 16.) This quantity expresses the time rate of change of own ship course.

Assuming own ship horizontal speed vector is directed along own ship centerline, the time rate of change of relative target bearing ***DB*** plus the time rate of change of own ship course ***DCo*** equals the time rate of change of true target bearing, ***DBy***. That is, ***DB***+***DCo***= ***DBy***.

Higher derivatives of angular motion. Higher derivatives of angular motion can be used to compute linear accelerations and higher derivatives of linear motion. The higher

derivatives of angular motion are symbolized in the same way as angular rates except a superscript numeral is applied to the ***D*** operator preceding the rate symbol to indicate the order of the derivative, as D^2 for second derivative (acceleration) and D^3 for third derivative. Higher order derivatives of angular motion are illustrated in figures 15 and 16 as they are in the same directions as their corresponding angular rates.

In composite tables 15 and 16, higher order derivatives are defined, and symbolized by adding a superscript numeral to the rate symbol. For example, in figure 16, the second derivative (acceleration) of stabilized angular elevation displacement measured with respect to the earth frame is illustrated as the vector 3–4. In composite table 16, this quantity is defined by replacing "angular rate" with "angular acceleration," and symbolized by adding the superscript numeral ***2***, forming symbol D^2E.

Motion Between Frames of Reference

Motions between own ship frame, earth frame, and the inertial frame are used to transform own ship and target motions between these frames.

Angular rates of motion in naval antiaircraft fire control can be considered in the following categories:

1. Motion of own ship frame with respect to the earth frame.
2. Motion of the earth frame with respect to the inertial frame.
3. Motion of own ship frame with respect to the inertial frame.

Motion between two frames requires the expression of the total translation rate of the one frame with respect to the other with useful components of this total translation rate, and the expression of the total rotation rate of one frame with respect to the other with useful components of this total rotation rate.

Motion of own ship frame with respect to the earth frame. The rates of motion between own ship frame and the earth frame are:

1. Translation rate of own ship frame with respect to the earth frame, and useful components of this total rate.
2. Rotation rate of own ship frame with respect to the earth frame, and useful components of this total rotation rate.

Translation Rates. The total translation rate of own ship frame with respect to the earth frame is symbolized ***(DMo)k***. This total rate with its useful components is discussed, illustrated, and symbolized under "Linear Motion" in this section.

Rotation Rates. The total rotation rate of own ship frame with respect to the earth frame is symbolized ***DI***. Useful components of this total angular rate are:

1. Rate components of own ship frame measured in elevation planes related to a specified bearing line.
2. Rate components of own ship frame measured about axes in the deck or horizontal planes related to a specified bearing line.
3. Rate components of own ship frame measured in the horizontal or deck planes with respect to north.

Rates of own ship frame measured in elevation planes are the motion quantities expressing the rates of change of level angles when related to the line of sight, and the rates of change of pitch angles when related to own ship centerline.

Rates of own ship frame measured about axes in the horizontal or deck planes are the motion quantities expressing the rates of change of cross-level angles when related to the line of sight, and the rates of change of roll angles when related to own ship centerline.

The rates of change of level angles, cross-level angles, roll angles, and pitch angles are expressed by applying the operator ***D*** to the symbols for the angles. These angles are discussed, defined, and symbolized in "Deck Inclination" under "Present Target Position" in this part. The angles are illustrated in figure 4.

For example, to express the rate of change of roll angle, symbol for the angle ***Zo*** is preceded by the operator ***D***, forming symbol ***DZo***. To express the rate of change of level angle measured between the horizontal and deck planes in the vertical plane through the line of sight, symbol for this angle ***Ei*** is preceded by the operator ***D***, forming symbol ***DEi***.

Rates of own ship frame measured in the horizontal or deck planes with respect to north

express the rates of change of true target bearing when related to the line of sight, and the rates of change of own ship course when related to own ship centerline. The symbols for the rates of change of true target bearings and own ship course are given in "Horizontal and deck angular rates" under "Angular Motion" in this part.

To express the rotation of one frame with respect to another frame a minimum of three useful rotation rates are required. In cases where the rotation rates are not related to the reference line in one of the frames, a fourth rotation rate expressing the rate of the reference line of the one frame with respect to the reference line of the other frame is required. For example, the rotation of own ship frame with respect to the earth frame is expressed by three rates when related to own ship centerline because own ship centerline is the reference line for own ship frame. These three rates are:

1. Rate of change of roll angle ***DZo***
2. Rate of change of pitch angle ***DEio***
3. Rate of change of own ship course ***DCo***

(assuming own ship speed vector is directed along own ship centerline)
However, when the rotation rates of own ship frame are measured about the line of sight as the specified bearing line, a fourth rotation rate expressing the rate of own ship centerline with respect to north is required. Therefore, a set of rotation rates about the line of sight as a specified bearing line are:

1. Rate of change of level angle ***DEi'***,
2. Rate of change of cross-level angle ***DZ***,
3. Rate of change of true target bearing ***DBy***, and
4. Rate of change of own ship course ***DCo*** (assuming own ship speed vector is directed along own ship centerline).

Motion of the earth frame with respect to the inertial frame. The only useful rates of the earth frame with respect to the inertial frame are the rotational rates. The total rotation rate of the earth with respect to the inertial frame is symbolized ***DIk***.

The expression of the three useful components of this total rate is best obtained by considering a method for measuring these rates.

To measure the rotation rates of the earth with respect to inertial space requires an instrument sensitive to motion with respect to the inertial frame. A gyro is an instrument which is capable of measuring these rates. To obtain the values we may mount three gyros as follows:

1. One gyro with its axis along the N–S line.
2. One gyro with its axis along the E–W line.
3. One gyro with its axis vertical (that is, perpendicular to the horizontal plane).

The precessional rate observed on the gyro mounted along the N–S line is symbolized ***DEik*** as this rate corresponds approximately to a level rate.

The precessional rate observed on the gyro mounted along the E–W line is symbolized ***DZk*** as this rate corresponds approximately to a cross-level rate.

The precessional rate observed on the gyro mounted along the vertical line is symbolized ***DBk*** as this rate corresponds approximately to a bearing rate.

Therefore, the rotation of the earth with respect to the inertial frame is expressed by the three rotational rates:

1. ***DEik***.
2. ***DZk***.
3. ***DBk***.

Motion of own ship frame with respect to the inertial frame. Motion between own ship frame and the inertial frame is expressed by combining the motions of own ship frame with respect to the earth frame, and the motions of the earth frame with respect to the inertial frame.

Projectile Velocity

The class of quantities expressing projectile velocities is indicated by the symbol ***U*** in the quantity. Projectile velocities are measured as initial projectile velocity or as average projectile velocity to the present or future target positions.

The basic projectile velocity quantity (represented by basic symbol ***U***) is the initial velocity of the projectile with respect to the gun muzzle at the instant the projectile leaves the gun. This velocity is independent of the reference frame used for the measurement.

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To express the average projectile velocities to the present and future target positions, numeral modifiers are applied to the basic symbol ***U***. Numeral modifier ***1*** is used for average velocity to the present target position, forming symbol ***U1***, and numeral modifier ***2*** is used for future target position, forming symbol ***U2***.

The average projectile velocity to the present target position multiplied by present time of flight equals present range. That is, $U1 \times T1 = R$.

The average projectile velocity to the future target position multiplied by time of flight equals future range. That is, $U2 \times T2 = R2$.

Frames of reference. The value of the average projectile velocity to the present and future target positions depends on the reference frame used by the fire control system.

To distinguish between frames to which average projectile velocities are referred, the symbol for the average velocity is enclosed in parentheses and followed by a quantity modifier to indicate the frame. Quantity modifiers used are:

Modifier	Referred to—
s	Inertial space.
k	Earth.
o	Frame rigidly attached to own ship.

For example, average projectile velocity to the present target position referred to the earth frame is symbolized $(U1)k$, and average projectile velocity to the future target position referred to the inertial frame is symbolized $(U2)s$.

These rules for using reference frame modifiers are applied only where there is possibility of confusion regarding the frames to which quantities are referred. If an entire discussion concerns one frame, modifiers may be omitted.

Time

The class of quantities expressing time is indicated by the symbol ***T*** in the symbol formed.

The basic time quantity (represented by symbol ***T***) is elapsed time. Other types of time quantities expressed are:

1. Time of flight.
2. Fuze time.
3. Dead time.

Time of flight. Time of flight is expressed either as time of flight to present target position or time of flight to future target position. Numeral modifier ***1*** is used for time of flight to present target position, forming symbol ***T1***, and numeral modifier ***2*** is used for time of flight to future target position forming symbol ***T2***. The time of flight to the future target position is the time quantity referred to by the general name "time of flight."

The change in the time of flight to the future target position during dead time is used in the computation of fuze setting. To express this time quantity, symbol ***T2*** is enclosed in parentheses and preceded by quantity modifier ***g***, forming symbol $g\,(T2)$.

Fuze time. To express fuze time (that is, fuze setting in seconds), basic time symbol ***T*** is modified by numeral ***5***, forming symbol ***T5***.

Fuze time is composed of the time of flight to the future target position plus the change in time of flight due to dead time. That is, $T5 = T2 + g\,(T2)$.

Dead time. Dead time is the time between the setting of the fuze and the firing of the projectile. Dead time is expressed by the basic time symbol ***T*** modified by ***g***, forming symbol ***Tg***.

Courses, Headings, and Target Angles

Courses, headings, and target angles are used to express the directions of own ship and target motions with respect to a reference line.

Courses. The class of quantities expressing angular measurements of the directions of own ship speed vector and target speed vector in the horizontal plane is called "courses," and is represented by the basic symbol ***C***.

All course angles are assumed to be measured in the horizontal plane from north.

The basic course quantity (represented by basic symbol ***C***) is the angle between the N-S vertical plane and the vertical plane through the relative target speed vector (referred to the frame used by the fire control system), measured in the horizontal plane clockwise from north.

Own ship course is the angle between the N-S vertical plane and the vertical plane through own ship speed vector (referred to the frame used by the fire control system), measured in the horizontal plane clockwise from north. To

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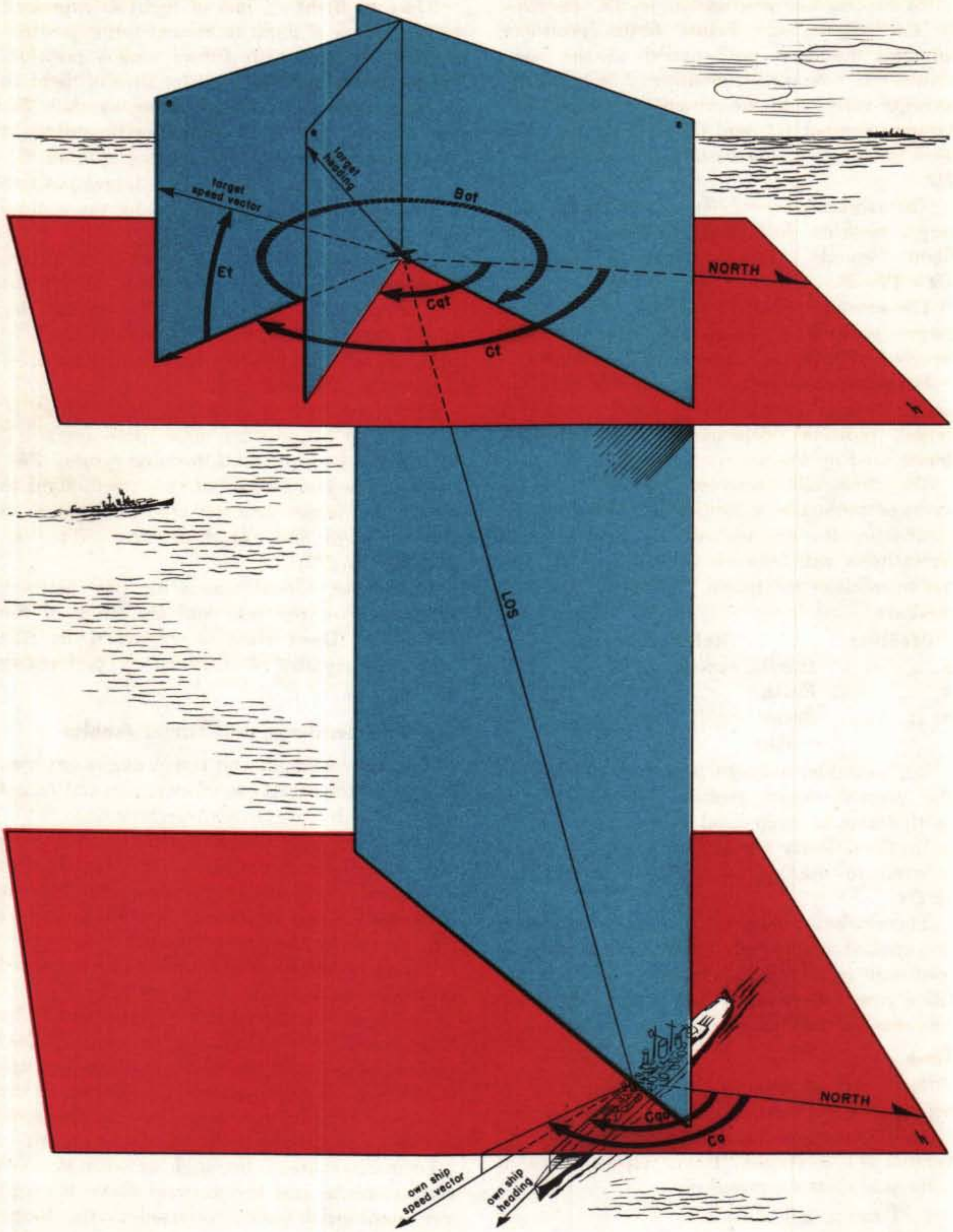

Figure 17.—Courses, Headings, and Target Angles.

express own ship course, basic course symbol ***C*** is modified by ***o***, forming symbol ***Co***. (See figure 17.)

Target course is the angle between the N-S vertical plane, and the vertical plane through the target speed vector (referred to the frame used by the fire control system), measured in the horizontal plane clockwise from north. To express target course, basic course symbol ***C*** is modified by ***t***, forming symbol ***Ct***. (See figure 17.)

Headings. The class of quantities expressing angular measurements of the directions of own ship centerline and target centerline in the horizontal plane is called "headings" and is represented by the basic symbol ***Cq***.

Own ship heading and target heading are measured in the horizontal plane from the N-S line.

Own ship heading is the angle between the N-S vertical plane and the vertical plane through own ship centerline measured in the horizontal plane clockwise from north. To express own ship heading, basic heading symbol ***Cq*** is modified by ***o***, forming symbol ***Cqo***. (See figure 17.)

Target heading is the angle between the N-S vertical plane and the vertical plane through the target centerline measured in the horizontal plane clockwise from north. To express target heading, basic heading symbol ***Cq*** is modified by ***t***, forming symbol ***Cqt***. (See figure 17.)

Target angles. Angles expressing the direction of the target speed vector with respect to the horizontal plane and the line of sight are:

1. Target angle, and
2. Angle of climb or dive.

TARGET ANGLE. Target angle is the angle from the vertical plane through the target speed vector (referred to the frame used by the fire control system) to the vertical plane through the line of sight measured in the horizontal plane, clockwise from the target speed vector. To express target angle, basic bearing symbol ***B*** is modified by ***o*** and ***t***, forming symbol ***Bot***. (See figure 17.)

ANGLE OF CLIMB OR DIVE. The angle of climb or dive is the angle between the horizontal plane and the target speed vector (referred to the frame used by the fire control system) measured upward from the horizontal plane in the vertical plane through the target speed vector. To express the angle of climb or dive, basic elevation symbol ***E*** is modified by ***t***, forming symbol ***Et***. (See figure 17.)

ANTIAIRCRAFT RELATED QUANTITIES

Chapter 3—Wind

Contents

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Chapter 3

WIND

Wind values are used to compute corrections to prediction quantities to account for the effect of wind on the projectile during the time of flight. The types of wind measured in determining these corrections are:

1. True wind—measure of air mass movement with respect to the earth. Because air mass movements are difficult to measure, true wind value used is a virtual value based upon measurements and weighted averages. This virtual value of true wind (ballistic wind) is of constant magnitude and direction, but has approximately the same effect on the projectile during the time of flight as the sum of the effects of the actual winds.

2. Own ship wind—resulting from velocity imparted to the projectile by the motion of own ship over the earth. Its measured value is equal to and opposite the rate of own ship over the earth. That is, a projectile fired from a moving ship is imparted with a velocity equal in magnitude and direction to own ship speed vector. When the air mass is stationary with respect to the earth (that is, true wind rate is zero), there is no wind blowing the projectile off its course. However, the stationary air mass resists the velocity imparted to the projectile by own ship motion, and its effect is to partially nullify this velocity. The resulting effect on the projectile is the same as if a wind were blowing with a magnitude equal to own ship speed, but in the opposite direction.

3. Apparent wind—resultant of the vector addition of own ship wind rate and true wind rate. This is the total wind acting to blow the projectile off its course, and is the actual wind value measured aboard own ship. Since one of its components is own ship wind, its value varies as own ship course and speed vary.

Reference planes used for measuring wind quantities are:

1. Horizontal plane.
2. Deck plane.

Reference lines used are:

1. Own ship centerline.
2. N–S line.
3. Line of sight.
4. Line of fire.

The classes of wind quantities used in computing corrections to prediction quantities are:

1. Wind bearings.
2. Wind courses.
3. Wind rates.
4. Wind jumps.

Wind Bearings

The class of quantities expressing angular measurements of the direction from which the wind is blowing in the horizontal and deck planes is called "wind bearings."

Wind bearing angles are measured in either the horizontal or deck planes. The angles are measured from:

1. Either own ship centerline or the N–S line to the vertical plane through the direction from which the wind is blowing, and

2. Direction from which the wind is blowing to either the vertical plane or normal plane through the line of sight or the line of fire.

The types of wind bearings expressed are:

1. True wind bearings.
2. Own ship wind bearings.
3. Apparent wind bearings.

True wind bearings. The basic wind bearing quantity (represented by symbol **B*w***) is the angle between the vertical plane through own ship centerline and the vertical plane through the direction from which the true wind is blowing measured in the horizontal plane. (See figure 18 and table 18A.)

When true wind bearing is measured in other ways, modifiers are applied to ***Bw*** in the order listed as follows:

Modifier	Measured
d	In deck.
y	From north.
s	To line of sight.
g	To line of fire.
'	To normal plane.

TABLES FOR FIGURE 18

Table 18A

<table>
<tr><td rowspan="14">Wind bearing</td><td colspan="3"></td><th colspan="2">From N–S vertical plane</th><th colspan="2">From vertical plane through OS CL</th></tr>
<tr><td rowspan="6">To vertical plane through direction from which wind is blowing clockwise</td><td rowspan="3">In horizontal plane</td><td>Own ship wind</td><td colspan="2">Bwyo [1–2]</td><td colspan="2"></td></tr>
<tr><td>True wind</td><td colspan="2">Bwy [1–2]</td><td colspan="2">Bw [3–2]</td></tr>
<tr><td>Apparent wind</td><td colspan="2">Bwya [1–2]</td><td colspan="2">Bwa [3–2]</td></tr>
<tr><td rowspan="3">In deck plane</td><td>Own ship wind</td><td colspan="2">Bwdyo [14–15]</td><td colspan="2"></td></tr>
<tr><td>True wind</td><td colspan="2">Bwdy [14–15]</td><td colspan="2">Bwd [13–15]</td></tr>
<tr><td>Apparent wind</td><td colspan="2">Bwdya [14–15]</td><td colspan="2">Bwda [13–15]</td></tr>
<tr><td colspan="3"></td><th>To vertical plane through LOS</th><th>To normal plane through LOS</th><th>To vertical plane through LOF</th><th>To normal plane through LOF</th></tr>
<tr><td rowspan="6">From vertical plane through direction from which wind is blowing clockwise</td><td rowspan="3">In horizontal plane</td><td>Own ship wind</td><td>Bwso [2–5]</td><td>Bwso' [2–6]</td><td>Bwgo [2–7]</td><td>Bwgo' [2–8]</td></tr>
<tr><td>True wind</td><td>Bws [2–5]</td><td>Bws' [2–6]</td><td>Bwg [2–7]</td><td>Bwg' [2–8]</td></tr>
<tr><td>Apparent wind</td><td>Bwsa [2–5]</td><td>Bwsa' [2–6]</td><td>Bwga [2–7]</td><td>Bwga' [2–8]</td></tr>
<tr><td rowspan="3">In deck plane</td><td>Own ship wind</td><td>Bwdso [15–12]</td><td>Bwdso' [15–11]</td><td>Bwdgo [15–10]</td><td>Bwdgo' [15–9]</td></tr>
<tr><td>True wind</td><td>Bwds [15–12]</td><td>Bwds' [15–11]</td><td>Bwdg [15–10]</td><td>Bwdg' [15–9]</td></tr>
<tr><td>Apparent wind</td><td>Bwdsa [15–12]</td><td>Bwdsa' [15–11]</td><td>Bwdga [15–10]</td><td>Bwdga' [15–9]</td></tr>
</table>

Table 18B

<table>
<tr><td rowspan="3">Wind course</td><td colspan="3"></td><th>Own ship wind</th><th>True wind</th><th>Apparent wind</th></tr>
<tr><td rowspan="2">From N–S vertical plane</td><td rowspan="2">To vertical plane through direction to which wind is blowing measured clockwise in</td><td>Horizontal plane</td><td>Cwo [1–17]</td><td>Cw [1–17]</td><td>Cwa [1–17]</td></tr>
<tr><td>Deck plane</td><td>Cwdo [14–16]</td><td>Cwd [14–16]</td><td>Cwda [14–16]</td></tr>
</table>

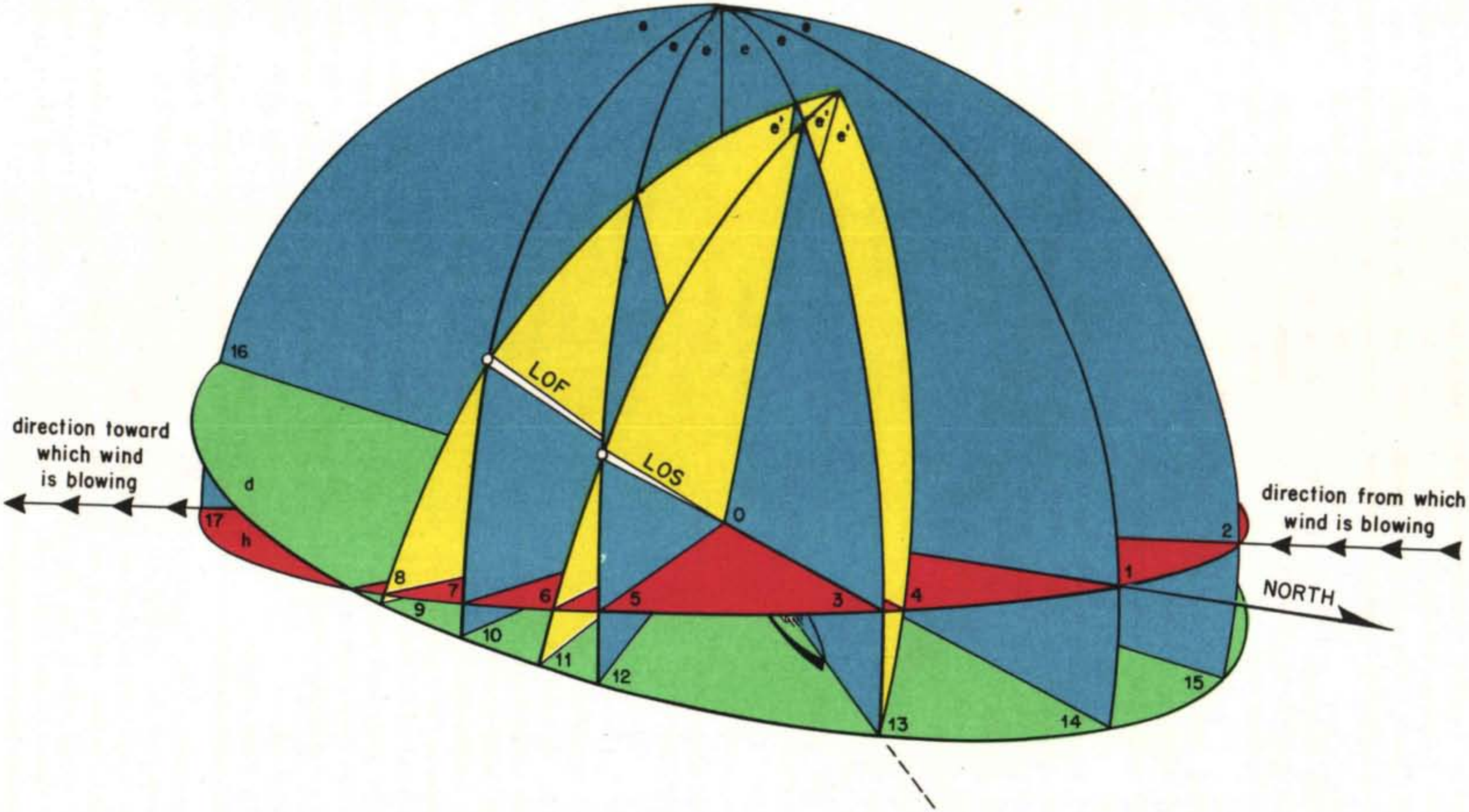

Figure 18.—Wind Bearings and Wind Courses.

When no prime modifier accompanies the symbol, true wind bearing quantity is measured between vertical planes. When no ***d*** is present, true wind bearing quantity is measured in the horizontal plane.

Own ship wind bearings. Own ship wind bearings are expressed by terminating the symbol for the same bearing angle of the true wind with modifier ***o***.

Apparent wind bearings. Apparent wind bearings are expressed by terminating the symbol for the same bearing angle of the true wind with modifier ***a***.

In figure 18, all angles expressing bearings of true wind, own ship wind, and apparent wind are shown with numerals indicating the arc measuring each bearing angle. In composite table 18A, each bearing angle is symbolized and defined. For example, in figure 18, bearing of the wind in the horizontal plane from the N–S vertical plane to the vertical plane through the direction from which the wind is blowing, is illustrated as the angle 1–2. In composite table 18A, this angle is defined and symbolized as:

1. ***Bwy*** (true wind).
2. ***Bwyo*** (own ship wind).
3. ***Bwya*** (apparent wind).

Wind Courses

The class of quantities expressing angular measurements of the direction toward which the wind is blowing in the horizontal and deck planes is called "wind courses".

Wind course angles are measured from the N–S vertical plane to the vertical plane through the direction toward which the wind is blowing. Course angles are measured in either the horizontal plane or the deck plane.

The types of wind courses expressed are:

1. True wind courses.
2. Own ship wind courses.
3. Apparent wind courses.

True wind courses. The basic wind course quantity (represented by symbol ***Cw***) is the angle measured in the horizontal plane from the N–S vertical plane to the vertical plane through the direction toward which the true wind is blowing. (See figure 18 and table 18B.)

When true wind course is measured in the deck plane, instead of the horizontal plane, modifier ***d*** is added, forming symbol ***Cwd***.

Own ship wind courses. Own ship wind courses are expressed by terminating the symbol for the same course of the true wind with modifier ***o***.

Apparent wind courses. Apparent wind courses are expressed by terminating the symbol for the same course of the true wind with modifier ***a***.

In figure 18, all angles used to express courses of true wind, own ship wind, and apparent wind are shown with numerals indicating the arc measuring the angle. In composite table 18B, each course angle is symbolized and defined. For example, in figure 18, the course of the wind in the horizontal plane from the N–S vertical plane to the vertical plane through the direction toward which the wind is blowing is illustrated as the angle 1–17. In composite table 18B, this angle is defined and symbolized as:

1. ***Cw*** (true wind).
2. ***Cwo*** (own ship wind).
3. ***Cwa*** (apparent wind).

Wind Rates

The class of quantities expressing rates of the wind is called "wind rates."

All wind rates are measured with respect to the earth. They are measured about either the

1. Line of fire, or
2. Line of sight.

Wind rates about the line of fire. The types of wind rates measured about the line of fire are:

1. True wind rates.
2. Own ship wind rates.
3. Apparent wind rates.

TRUE WIND RATES. The basic wind rate quantity (symbolized by basic symbol ***W***) is the total rate of the true wind measured with respect to the earth; this quantity is called "true wind speed." (See figures 19 and 20 and table 19.)

Components of true wind speed are expressed by applying modifiers to the basic symbol ***W***. Modifiers and their meanings are as follows:

Modifier	Component
b	In horizontal, perpendicular to vertical plane through line of fire.

Modifier	Component
bd	In deck, perpendicular to normal plane through line of fire.
d	In deck, in normal plane through course line.
e	Perpendicular to line of fire, in vertical plane through line of fire.
e'	Perpendicular to line of fire, in normal plane through line of fire.
g	Total, perpendicular to line of fire.
h	In horizontal, in vertical plane through course line.
r	In range, along line of fire.
rd	In deck range, in normal plane through line of fire.
rh	In horizontal range, in vertical plane through line of fire.
v	In vertical range, in vertical plane through line of fire.
v'	In normal range, in normal plane through line of fire.

North-South and East-West True Wind Rates. Projections of true wind rates are expressed by adding modifier ***y*** for N–S projections, and modifier ***x*** for E–W projections.

Own Ship Wind Rates. Own ship wind rates are expressed by terminating the symbol for the same rate of true wind with modifier ***o***.

Apparent Wind Rates. Apparent wind rates are expressed by terminating the symbol for the same rate of the true wind with modifier ***a***.

Figures 19 through 22 show all wind rates measured about the line of fire. Figure 19 shows wind rate components measured in stable coordinates, figure 20 wind rate components measured in unstable coordinates, figure 21 stable wind rate components in the N–S and E–W directions, and figure 22 unstable wind rate components in the N–S and E–W directions. In composite tables 19, 20, 21, and 22, each wind rate quantity is defined and symbolized. For example, in figure 19, wind rate measured along the line of fire is illustrated as the vector 0–5. In composite table 19, this wind rate is defined and symbolized as:

1. ***Wr*** (true wind).
2. ***Wro*** (own ship wind).
3. ***Wra*** (apparent wind).

Wind rates about the line of sight. In general, to express rates of true wind, own ship wind, and apparent wind measured about the line of sight, symbol for the same rate measured about the line of fire is terminated with modifier ***s***.

However, when rates measured about the lines of sight and fire are identical, the symbol for the rate about the line of fire is used. For example, vertical true wind rate in the vertical plane through the line of fire is identical in magnitude and direction to vertical true wind rate in vertical plane through the line of sight. Therefore, this rate is symbolized ***Wv***.

Also, total rates perpendicular to the line of sight are symbolized by replacing the modifier ***g***, in total rates perpendicular to the line of fire, with modifier ***s***. For example, total true wind rate perpendicular to line of fire is symbolized ***Wg***, the corresponding rate perpendicular to the line of sight is symbolized ***Ws***.

Wind rates measured about the line of sight are illustrated in figures 19 and 20 by replacing line of fire with line of sight. These wind rates are illustrated by the same vectors as used to illustrate line of fire rates because orientation of rate components about the line of sight is the same as orientation of rate components about the line of fire. In composite tables 19 and 20, these rates are defined by replacing line of fire with line of sight, and symbolized by adding modifier ***s*** to the line of fire symbol. For example, in figure 19, wind rate measured along line of sight is illustrated as vector 0–5 by replacing LOF with LOS. In composite table 19, this rate is defined by replacing "line of fire" with "line of sight," and symbolized by adding modifier ***s*** to line of fire symbol as:

1. ***Wrs*** (true wind).
2. ***Wros*** (own ship wind).
3. ***Wras*** (apparent wind).

Windage Jumps

The class of quantities expressing angular deviation of the projectile as it leaves the gun muzzle due to a relative wind velocity at right angles to the line of fire is called "wind jump". The wind jump symbol is made up of the basic

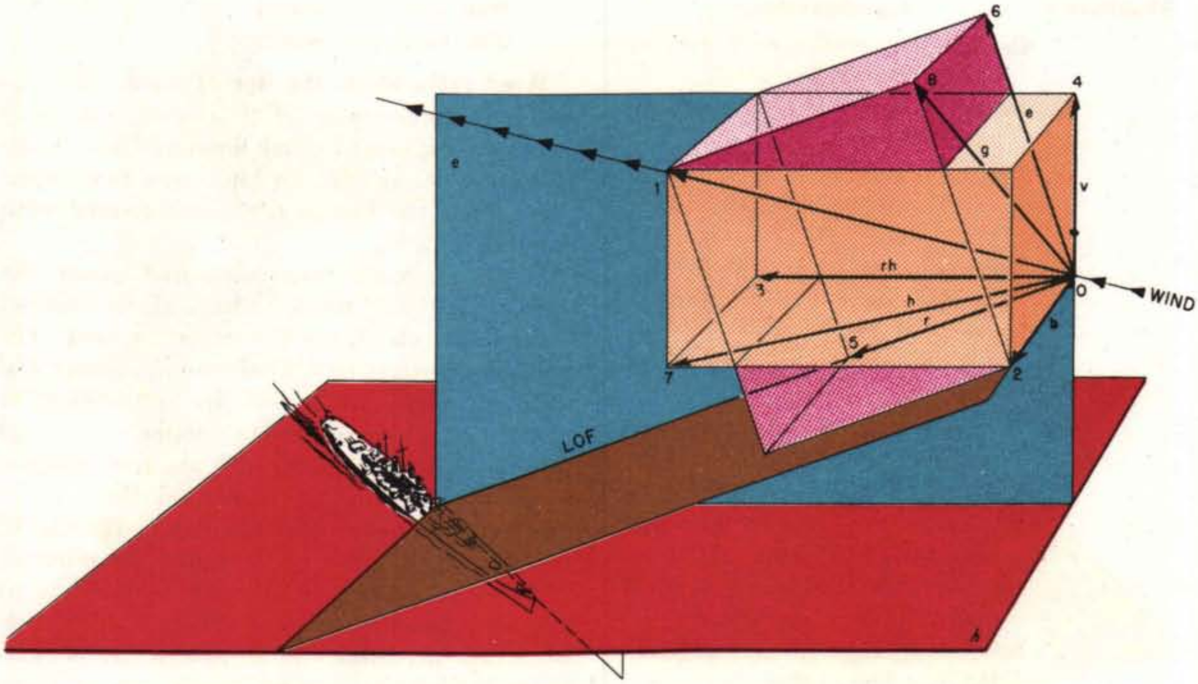

Figure 19.—Wind Rates About Line of Fire in Stable Coordinates.

TABLE FOR FIGURE 19

	True wind		Own ship wind	Apparent wind
Total rate	***W***	0–1	***Wo***	***Wa***
Rate perpendicular to vertical plane through LOF	***Wb***	0–2	***Wbo***	***Wba***
Rate in horizontal in vertical plane through LOF	***Wrh***	0–3	***Wrho***	***Wrha***
Rate in vertical in vertical plane through LOF	***Wv***	0–4	***Wvo***	***Wva***
Rate along LOF	***Wr***	0–5	***Wro***	***Wra***
Rate perpendicular to LOF in vertical plane through LOF	***We***	0–6	***Weo***	***Wea***
Rate in horizontal in vertical plane through course line	***Wh***	0–7	***Who***	***Wha***
Total rate perpendicular to LOF	***Wg***	0–8	***Wgo***	***Wga***

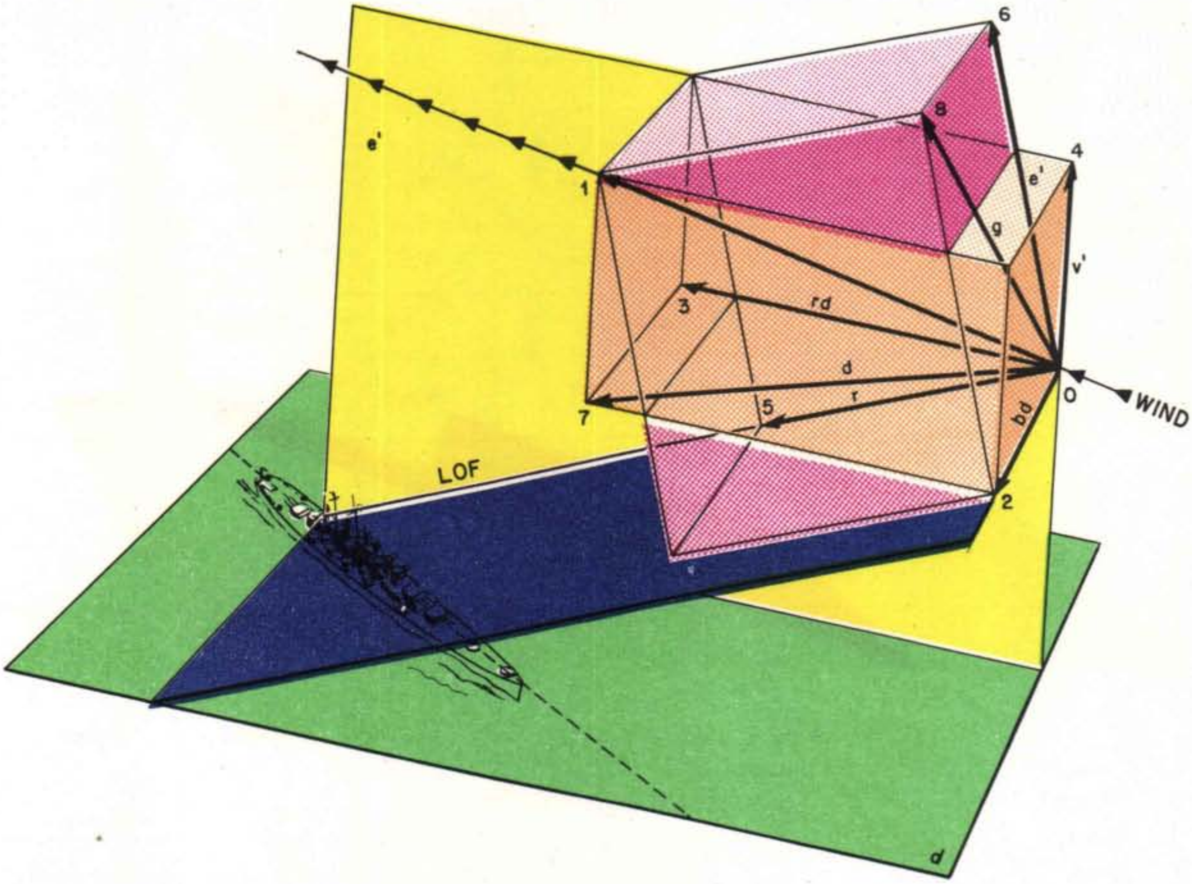

Figure 20.—Wind Rates About Line of Fire in Unstable Coordinates.

TABLE FOR FIGURE 20

	True wind	Own ship wind	Apparent wind
Total rate	***W*** 0–1	***Wo***	***Wa***
Rate perpendicular to normal plane through LOF	***Wbd*** 0–2	***Wbdo***	***Wbda***
Rate in deck in normal plane through LOF	***Wrd*** 0–3	***Wrdo***	***Wrda***
Rate along a line normal to deck	***Wv'*** 0–4	***Wvo'***	***Wva'***
Rate along LOF	***Wr*** 0–5	***Wro***	***Wra***
Rate perpendicular to LOF in normal plane through LOF	***We'*** 0–6	***Weo'***	***Wea'***
Rate in deck in normal plane through course line	***Wd*** 0–7	***Wdo***	***Wda***

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TABLE FOR FIGURE 21

		True wind	Own ship wind	Apparent wind
Projection of rate (W) in	N–S vertical plane	***Wy*** 0–2	***Wyo***	***Wya***
	E–W vertical plane	***Wx*** 0–1	***Wxo***	***Wxa***
Projection of rate (Wh) in	N–S vertical plane	***Why*** 0–3	***Whyo***	***Whya***
	E–W vertical plane	***Whx*** 0–4	***Whxo***	***Whxa***

TABLE FOR FIGURE 22

		True wind	Own ship wind	Apparent wind
Projection of rate (Wd) in	N–S normal plane	***Wdy*** 0–1	***Wdyo***	***Wdya***
	E–W normal plane	***Wdx*** 0–2	***Wdxo***	***Wdxa***

jump symbol ***J*** followed by the modifier ***w***, forming symbol ***Jw***. If required, symbols for angular components of ***Jw*** in various planes are expressed by applying the same basic symbol modifiers used for angular movement ***S*** listed under "Motion" in this section.

Wind Corrections

As stated in the introduction to "Wind," the purpose of computing wind values is to determine corrections to prediction quantities for the effect of wind on the projectile during the time of flight. These corrections are applied by:

1. Adjusting linear or angular motion quantities for wind effect, or
2. Computing angular corrections to lead angles (sight angle and sight deflection) accounting for wind effect.

To express the corrections to motion and lead angle quantities accounting for the effect of wind, the quantity is enclosed in parentheses and preceded by the quantity modifier ***w***. For example, the correction to range rate ***DMr*** for the effect of wind is symbolized ***w*(*DMr*)**.

To express a quantity corrected for the effect of wind, the quantity is enclosed in parentheses and followed by the quantity modifier ***w***. For example, range rate ***DMr*** corrected for wind effect is symbolized **(*DMr*)*w***.

Thus $DMr + w(DMr) = (DMr)w$ means range rate plus the correction to range rate for the effect of wind equals range rate corrected for wind effect.

Symbolization Problems

This part of the book is established as a reference for wind quantities whose symbolization is made difficult because of the way in which the fire control instrument combines quantities. That is, it is provided to establish and maintain standard symbols for quantities whose symbols may be constructed in more than one way.

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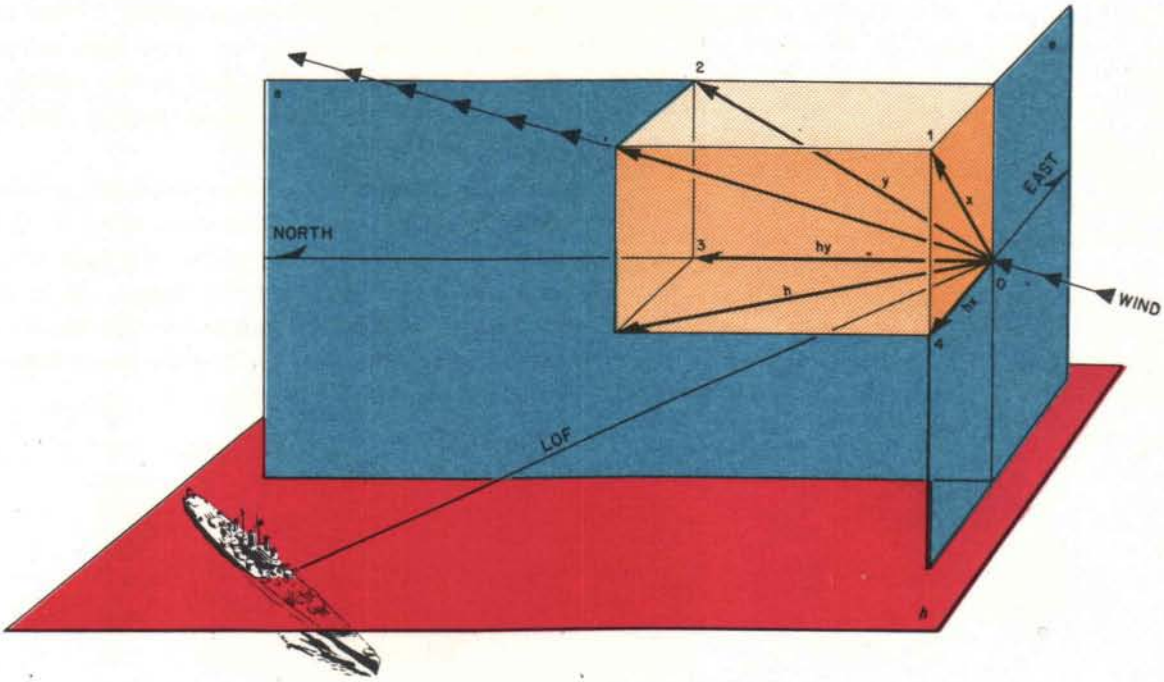

Figure 21.—North-South and East-West Projections of Wind Rates in Stable Coordinates.

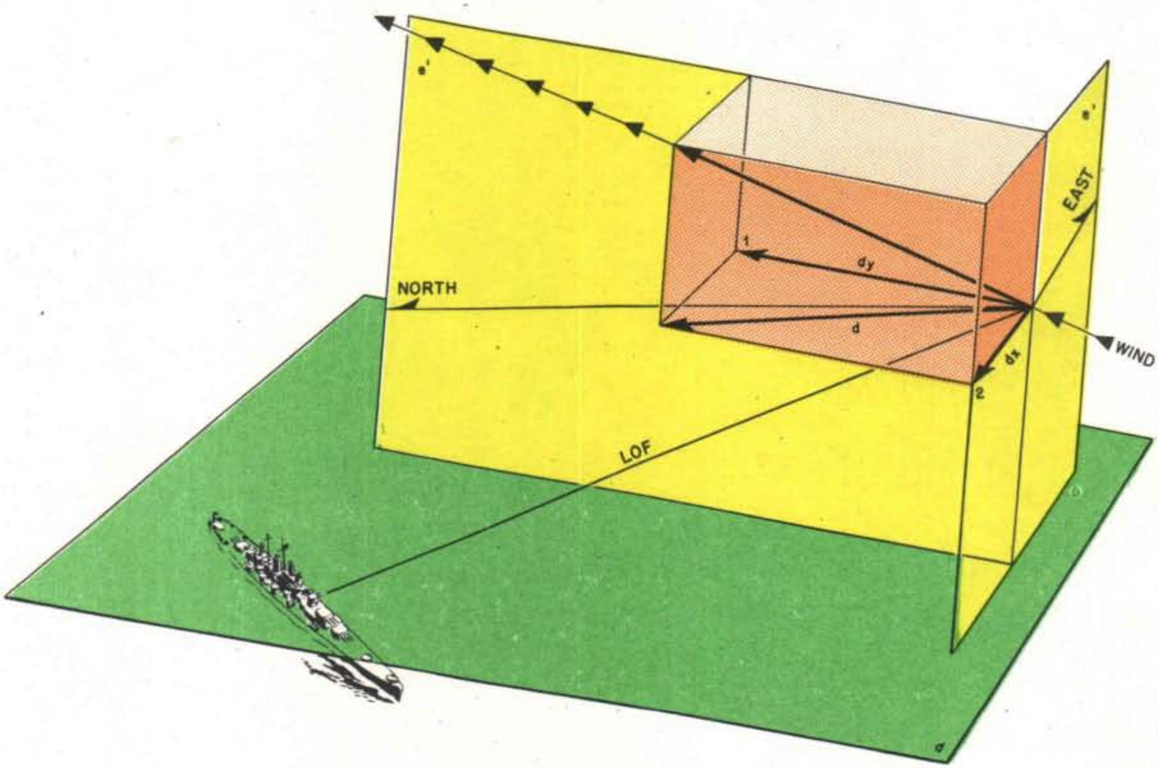

Figure 22.—North-South and East-West Projections of Wind Rates in Unstable Coordinates.

One such group of quantities is used in Gun Fire Control System Mk 63 where gun train order plus own ship course are subtracted from true bearing true wind to obtain predicted true wind angle; that is, $\boldsymbol{Bwy}-(\boldsymbol{Co}+\boldsymbol{Bdg'})=\boldsymbol{Bwg}$. Since own ship course, true bearing true wind, and predicted true wind angle are measured in the horizontal plane, and gun train order is measured in the deck plane, these quantities can be mathematically combined only by correcting gun train order to the horizontal plane. Therefore, since gun train order should be measured in the horizontal plane to form a correct summation, it may be symbolized ***Bg'***. However, since the actual value of gun train order used in the addition is measured in the deck plane, it may also be symbolized ***Bdg'***.

To avoid confusion, the standard symbol ***Bdg'*** is established for gun train order in this addition. That is, the symbols for this addition are $\boldsymbol{Bwy}-(\boldsymbol{Co}+\boldsymbol{Bdg'})=\boldsymbol{Bwg}$. To justify the symbol ***Bdg'*** for gun train order, the summation is considered to apply at the instant when the deck plane is horizontal.

ANTIAIRCRAFT RELATED QUANTITIES

Chapter 4—Linear and Angular Offsets

Contents

Chapter 4

LINEAR AND ANGULAR OFFSETS

Linear and angular offsets are used to establish the position of the line of fire with respect to the line of sight. The offsets are computed for and applied in the traverse and elevation planes as the parts making up sight angle and sight deflection. These parts of sight angle and sight deflection are composed of two types of offsets:

1. Those due to target motion in frame used by fire control system.

2. Those due to ballistics (wind effect, I. V. changes, etc.).

In computing the offsets, besides present target position, three additional positions are determined as follows:

1. Future target position—the position the target occupies at the end of the time of flight. That is, the position of the target when it is hit by the projectile. The location of this position is determined solely from target motion during the time of flight in the frame used by the fire control system.

2. Advance position—range tables are based on standard ballistic conditions such as no wind and designed initial velocity. When ballistic conditions are not standard, the sight angle and sight deflection obtained by entering the range tables with range and elevation of the future target position are in error causing the projectile

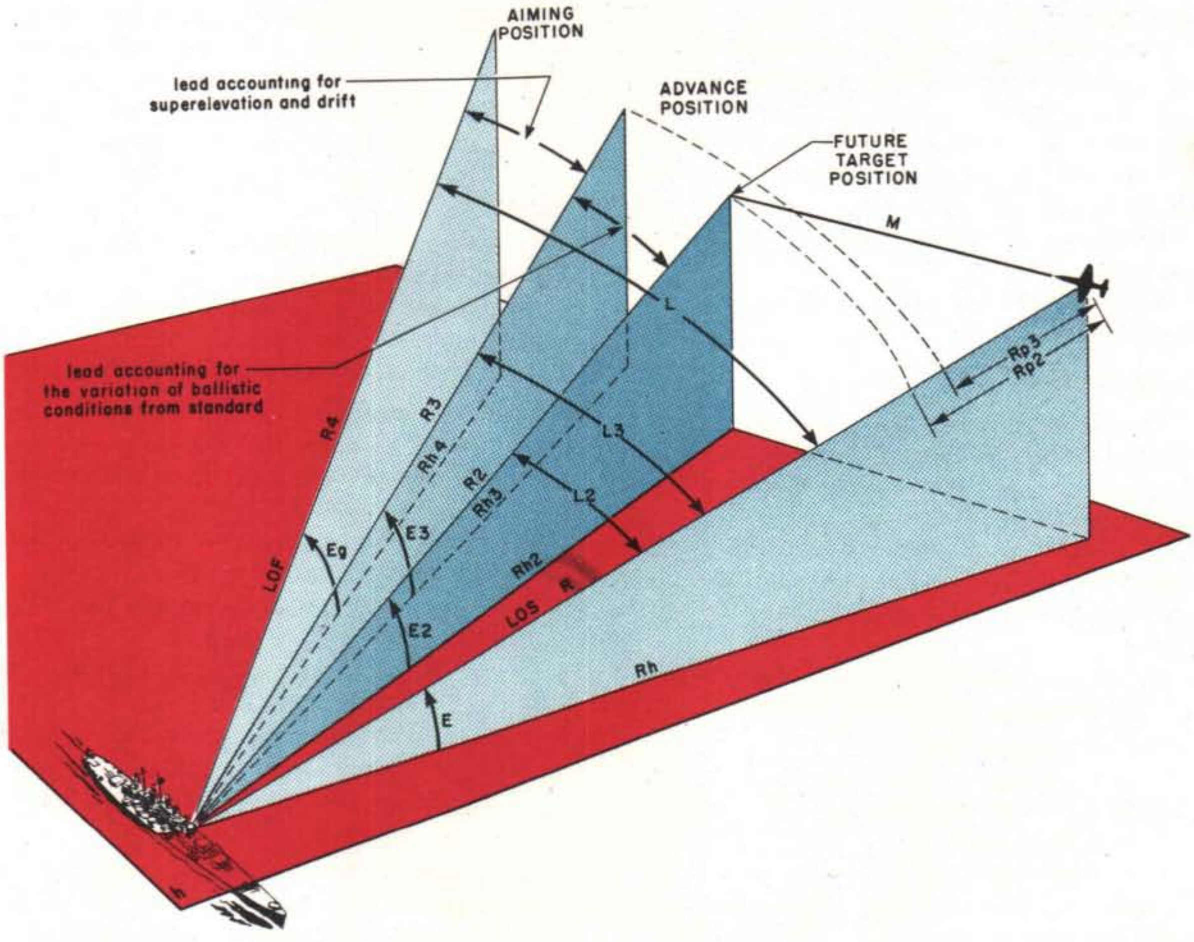

Figure 23.—Offsets to Future, Advance, and Aiming Positions and Range Predictions.

to miss the target. The errors are due to the changes in the trajectory caused by the variations from standard of the ballistics.

To obtain a hit, the range table is entered with the range and elevation of a different point called the "advance position." The advance position is selected so that the amount by which the projectile misses the advance position due to variations from standard ballistic conditions is just enough to cause the projectile to hit the future target position.

3. Aiming position—the position through which the line of fire passes. This position differs from the advance position by the superelevation and drift offset corrections. These offset corrections are obtained by entering the range tables for the gun with the elevation and range of the advance position.

The locations of the various target positions, and the offsets determining these positions are illustrated in figure 23.

In the expression of linear and angular offsets, the quantities measured or computed are:

1. Total offsets between the line of sight and line of fire (sight angles and sight deflections).
2. Individual offsets to account for wind, initial velocity changes, etc.
3. Offsets to future, advance, and aiming positions.
4. Coordinates of future, advance, and aiming positions.

Total Offsets

The class of quantities expressing angular offsets between the line of sight and the line of fire measured in traverse planes is called "sight deflections."

The class of quantities expressing angular offsets between the line of sight and the line of fire measured in elevation planes is called "sight angles."

Reference planes used for the measurements of sight angles and sight deflections are:

1. Horizontal plane.
2. Deck plane.

Reference lines used are:

1. Line of sight.
2. Elevation axis.

Measurements of sight angles and sight deflections are determined by the way in which the elevation and traverse axes are mounted. That is, the magnitudes of the angles depend on whether the elevation axis supports the traverse axis, or the traverse axis supports the elevation axis. For example, a stabilized director whose elevation axis supports the traverse axis applies sight angle in the vertical plane through the line of sight, and sight deflection in the slant plane through the elevation axis in the horizontal and through the line of fire (fig. 24). A stabilized director whose traverse axis supports the elevation axis applies sight deflection in the slant plane through the line of sight and through the elevation axis in the horizontal, and sight angle in the plane through the line of fire normal to the slant plane (fig. 25).

Sight deflection. The basic sight deflection quantity (represented by basic symbol ***L***) is the total lead angle between the line of sight and the line of fire.

Portions of this total lead angle measured in traverse planes (sight deflections) are symbolized by applying modifiers to basic symbol ***L*** to indicate the plane in which the sight deflection is measured. When the first modifier is ***s***, ***g***, ***2***, or ***3***, plane of measurement is a slant plane:

Through director elevation axis----------	***s***
Through gun elevation axis-------------	***g***
Through line of sight and future target position----------------------------	***2***
Through line of sight and advance position-	***3***

When no additional modifiers appear, slant plane passes through the line of sight, and elevation axis is stabilized to the horizontal plane.

Other letters appearing after the ***s*** or ***g*** have the following meaning:

d-------	Elevation axis is unstabilized and lies in deck plane.
g-------	Slant plane passes through line of fire.
2-------	Slant plane passes through line to future target position.
3-------	Slant plane passes through line to advance position.

Sight deflections are further modified to indicate planes from (and to) which the offsets are measured. To indicate the plane to which the offset is measured, sight deflection

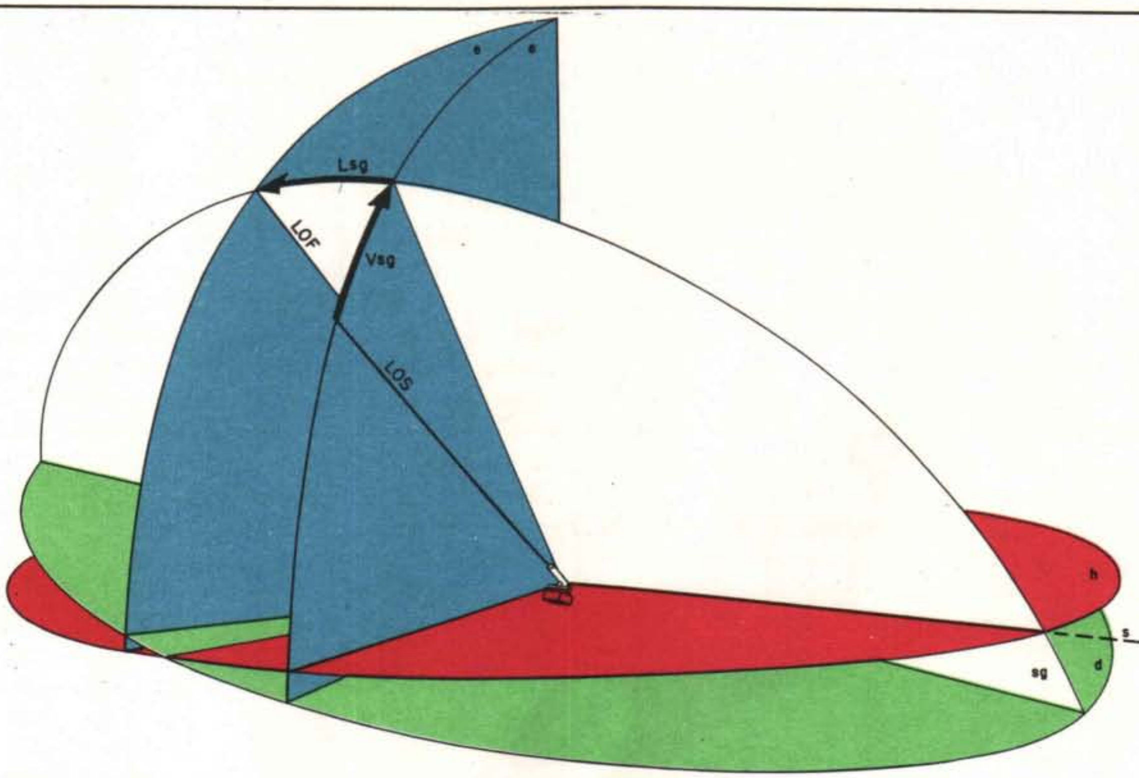

Figure 24.—Sight Deflection and Sight Angle for a Stabilized Director (Elevation Axis Supporting Traverse Axis).

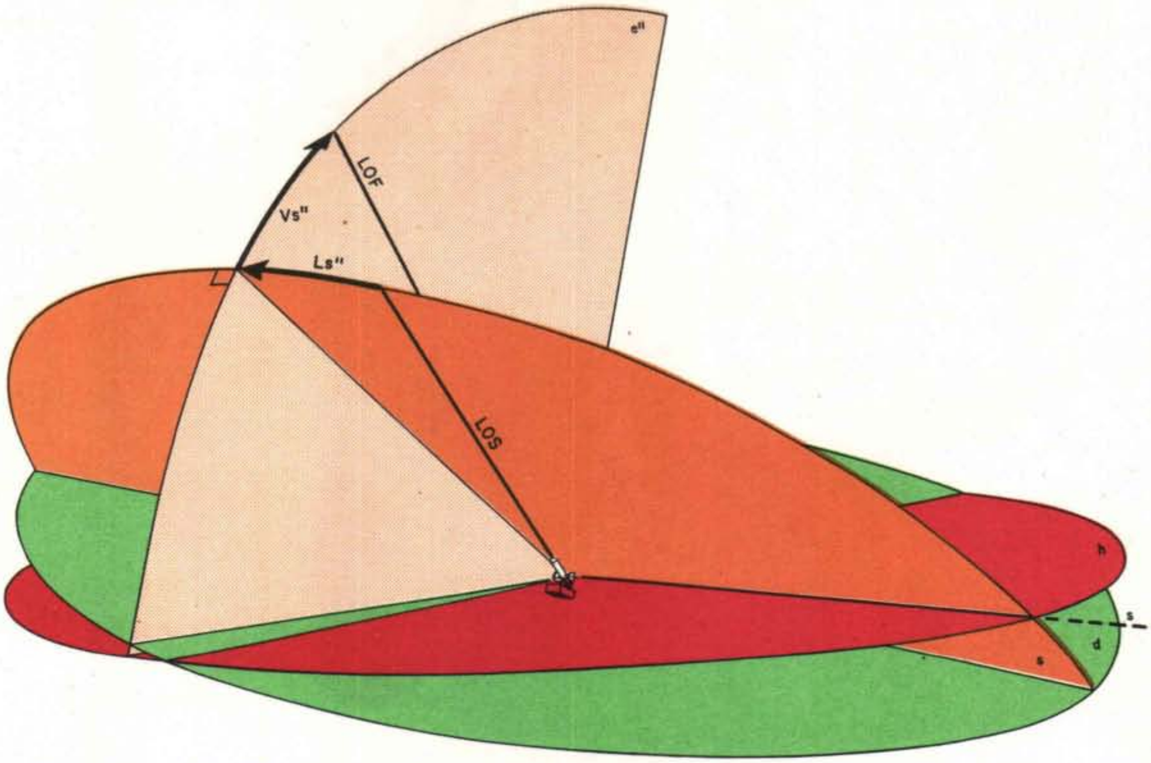

Figure 25.—Sight Deflection and Sight Angle for a Stabilized Director (Traverse Axis Supporting Elevation Axis).

TABLE FOR FIGURE 26

				In vertical plane through LOF	In normal plane through LOF
Total sight angle	From LOF to slant plane through LOS and through the	Director elevation axis in the	Horizontal	*Vs* 10–2	*Vs'* 10–3
			Deck	*Vsd* 10–4	*Vsd'* 10–5
		Gun elevation axis in the	Horizontal	*Vg* 10–6	*Vg'* 10–7
			Deck	*Vgd* 10–8	*Vgd'* 10–9
				In vertical plane through LOS	In normal plane through LOS
	From LOS to slant plane through LOF and through the	Director elevation axis in the	Horizontal	*Vsg* 1–11	*Vsg'* 1–12
			Deck	*Vsdg* 1–13	*Vsdg'* 1–14
		Gun elevation axis in the	Horizontal	*Vgg* 1–15	*Vgg'* 1–16
			Deck	*Vgdg* 1–17	*Vgdg'* 1–18
				To vertical plane through LOF	To normal plane through LOF
Total sight deflection	From LOS in a slant plane through LOS and through the	Director elevation axis in the	Horizontal	*Ls* 1–2	*Ls'* 1–3
			Deck	*Lsd* 1–4	*Lsd'* 1–5
		Gun elevation axis in the	Horizontal	*Lg* 1–6	*Lg'* 1–7
			Deck	*Lgd* 1–8	*Lgd'* 1–9
				From vertical plane through LOS	From normal plane through LOS
	To LOF in a slant plane through LOF and through the	Director elevation axis in the	Horizontal	*Lsg* 11–10	*'Lsg* 12–10
			Deck	*Lsdg* 13–10	*'Lsdg* 14–10
		Gun elevation axis in the	Horizontal	*Lgg* 15–10	*'Lgg* 16–10
			Deck	*Lgdg* 17–10	*'Lgdg* 18–10
				From vertical plane through LOS	From normal plane through LOS
Horizontal and deck deflection	In horizontal plane	To vertical plane through LOF		*Lh* 19–21	*'Lh* 20–21
		To normal plane through LOF		*Lh'* 19–26	*'Lh'* 20–26
				From vertical plane through LOS	From normal plane through LOS
	In deck plane	To vertical plane through LOF		*Ld* 23–25	*'Ld* 24–25
		To normal plane through LOF		*Ld'* 23–22	*'Ld'* 24–22

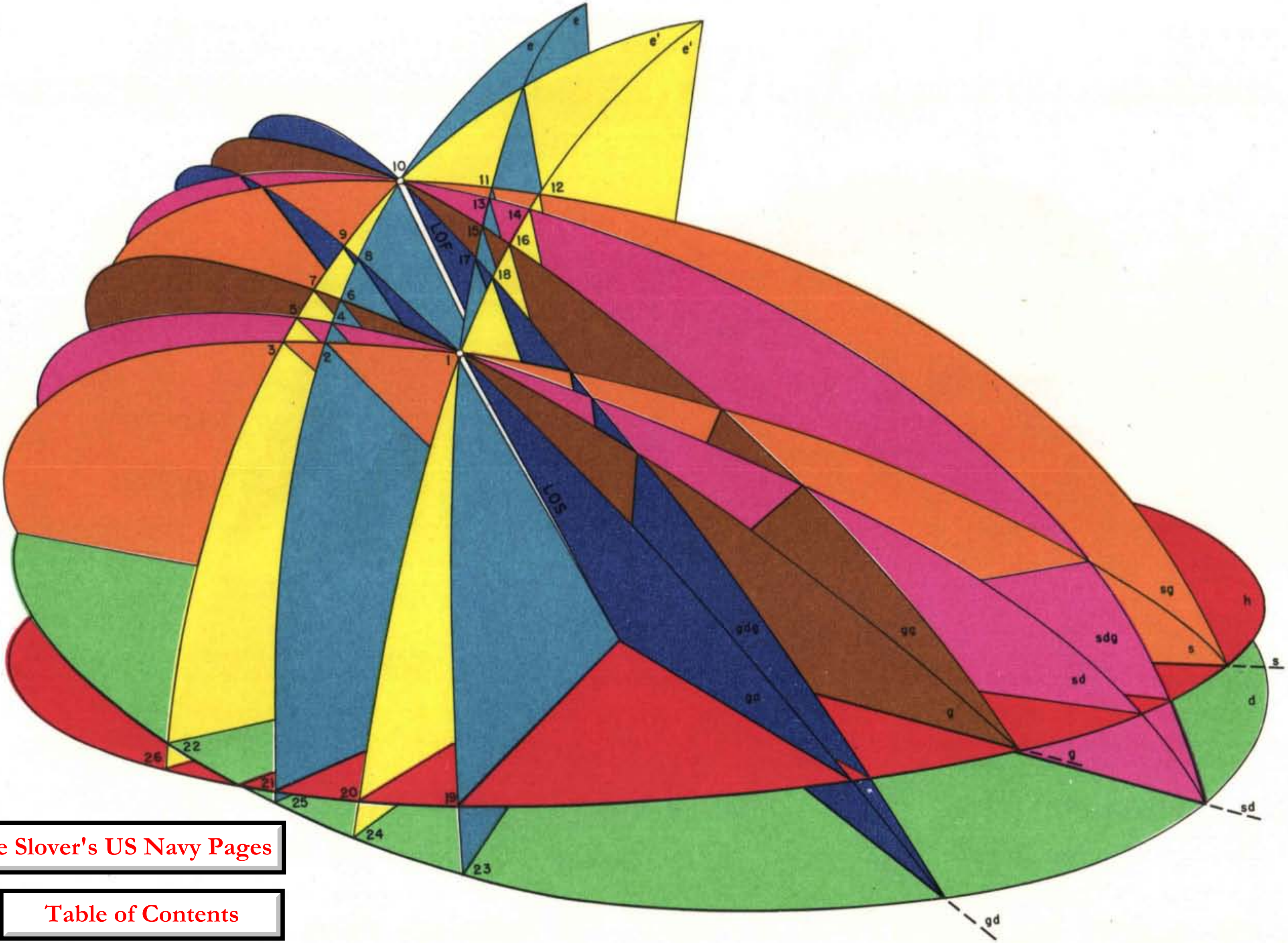

Figure 26.—Sight Deflections and Sight Angles (Elevation Axis Supporting Traverse Axis).

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TABLE FOR FIGURE 27

Total sight angle				In plane through LOF normal to slant plane in which traverse lead angle applied	
	From LOF to slant plane through LOS and through the	Director elevation axis in the	Horizontal	*Vs''*	6-2
			Deck	*Vsd''*	6-3
		Gun elevation axis in the	Horizontal	*Vg''*	6-4
			Deck	*Vgd''*	6-5
				In plane through LOS normal to slant plane in which traverse lead angle applied	
	From LOS to slant plane through LOF and through the	Director elevation axis in the	Horizontal	*Vsg''*	1-7
			Deck	*Vsdg''*	1-8
		Gun elevation axis in the	Horizontal	*Vgg''*	1-9
			Deck	*Vgdg''*	1-10
Total sight deflection				To plane through LOF normal to slant plane in which traverse lead angle is applied	
	From LOS in a slant plane through LOS and through the	Director elevation axis in the	Horizontal	*Ls''*	1-2
			Deck	*Lsd''*	1-3
		Gun elevation axis in the	Horizontal	*Lg''*	1-4
			Deck	*Lgd''*	1-5
				To plane through LOS normal to slant plane in which traverse lead angle is applied	
	From LOF in a slant plane through LOF and through the	Director elevation axis in the	Horizontal	*Lsg''*	6-7
			Deck	*Lsdg''*	6-8
		Gun elevation axis in the	Horizontal	*Lgg''*	6-9
			Deck	*Lgdg''*	6-10
Horizontal and deck deflection				From vertical plane through LOS	From normal plane through LOS
	In horizontal plane	To vertical plane through LOF		*Lh*	*'Lh*
		To normal plane through LOF		*Lh'*	*'Lh'*
				From vertical plane through LOS	From normal plane through LOS
	In deck plane	To vertical plane through LOF		*Ld*	*'Ld*
		To normal plane through LOF		*Ld'*	*'Ld'*

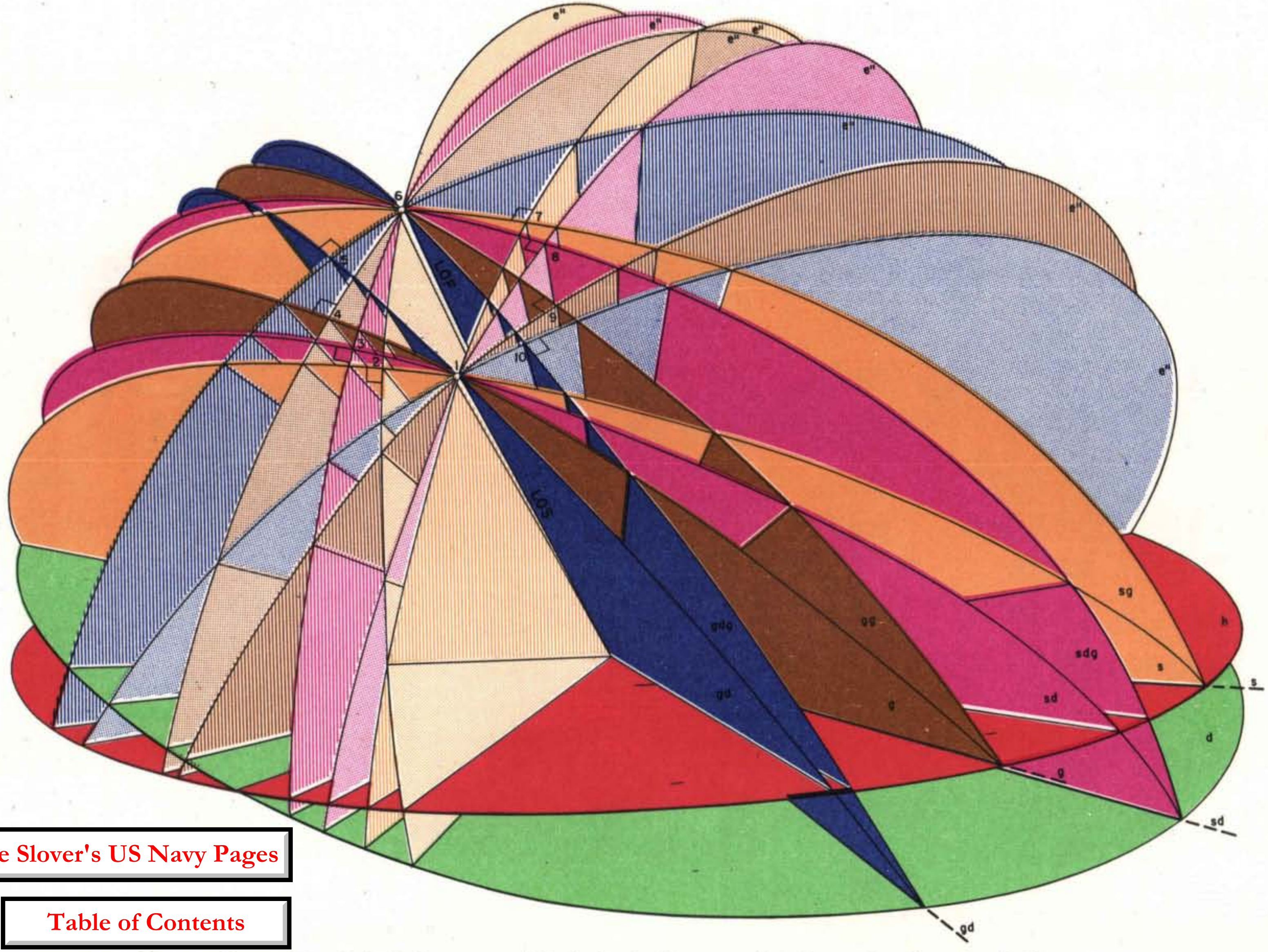

Figure 27.—Sight Deflections and Sight Angles (Traverse Axis Supporting Elevation Axis).

symbol is followed by ′ (prime) for a plane normal to the deck plane, and by a ″ (double prime) for a plane normal to the slant plane in which the traverse lead is applied. To indicate the plane from which the offset is measured, sight deflection symbol is preceded by the appropriate ′ (prime) or ″ (double prime) modifier.

Sight angle. The basic sight angle quantity (represented by basic symbol ***V***) is the total elevation difference between the line of sight and the line of fire measured in a vertical plane.

Elevation offsets, made in combination with lateral offsets, are symbolized by using the basic sight angle symbol ***V***, modified by designation for the traverse plane from (or to) which the measurement is made.

Sight angles are further modified to indicate the elevation plane in which the offset is measured. Sight angles are followed by a ′ (prime) to indicate measurement in a plane normal to the deck plane, and by a ″ (double prime) to indicate measurement in a plane normal to the slant plane in which the traverse lead angle is applied. When no ′ (prime) or ″ (double prime) appears, sight angle is measured in a vertical plane.

Figures 26 and 27 show all the values of sight angle and sight deflection with numerals to indicate the arc measuring each angle. Figure 26 shows sight angles and sight deflections measured when the elevation axis supports the traverse axis, and figure 27 shows sight angles and sight deflections measured when the traverse axis supports the elevation axis.

In composite tables 26 and 27 each sight angle and sight deflection is defined and symbolized.

For example, in figure 26 sight deflection in the slant plane through the line of sight and through the director elevation axis in the deck plane, measured from the line of sight to the normal plane through the line of fire is illustrated as the angle 1–5. In composite table 26 this angle is defined and symbolized ***Lsd′***.

In figure 26, sight angle measured in the normal plane through the line of sight, from the line of sight to the slant plane through the line of fire and through the director elevation axis in the horizontal plane is illustrated as the angle 1–12. In composite table 26, this angle is defined and symbolized ***Vsg′***. As stated, this sight angle is measured to the slant plane through the line of fire and through the director elevation axis in the horizontal plane. The designation for this slant plane is ***sg***. Since sight angles are modified to indicate the plane from (or to) which they are measured, the designation ***sg*** for the slant plane is applied to the basic sight angle symbol.

Horizontal and deck deflections. Besides expressing sight angles and sight deflections, the total offsets measured in the horizontal plane or in the deck plane are required for the computation of gun orders.

To indicate total offsets measured in the horizontal plane (horizontal deflections), basic sight deflection symbol ***L*** is modified by ***h;*** to indicate total offsets measured in the deck plane (deck deflections), basic sight deflection symbol ***L*** is modified by ***d***.

The angles are further modified to indicate the plane from (or to) which the measurements are made. To indicate the plane to which the offset is measured, the symbol is followed by ′ (prime) for a plane normal to the deck plane; to indicate the plane from which the offset is measured, the symbol is preceded by ′ (prime) for a plane normal to the deck plane. When no prime modifiers appear, the offsets are measured between vertical planes.

Figure 26 shows all the values of horizontal deflection and deck deflection with numerals to indicate the arc measuring each angle. In composite table 26, each offset is defined and symbolized. For example, in figure 26, deflection in the deck plane, measured from the normal plane through the line of sight to the vertical plane through the line of fire, is illustrated as the angle 24–25. In composite table 26, this angle is defined and symbolized ***′Ld***.

Individual Offsets

As stated in the introduction to "Linear and Angular Offsets," total lead angles (sight angles and sight deflections) are composed of individual portions accounting for specific factors as wind, relative motion, etc. To symbolize these individual parts, the symbol for the lead angle is enclosed in parentheses and preceded by the appropriate quantity modifier

or quantity modifiers to indicate that portion of the offset.

Quantity modifiers and their meanings are:

w	Wind.
u	Initial velocity.
m	Relative motion.
b	Ballistics.
p	Gun parallax.
ps	Director parallax.

For example, the portion of sight deflection ***Lsd*** accounting for wind is symbolized ***w*** (***Lsd***), and the portion of sight angle ***Vs*** accounting for relative motion and superelevation is symbolized ***mb***(***Vs***).

Rate of Change of Lead Angle

To obtain smooth inputs, disturbed line of sight computing systems use a feedback proportional to the rate of change of lead angles (sight angles and sight deflections).

To express the rate at which a lead angle is changing, symbol for the lead angle is preceded by the operator ***D*** (meaning time rate of change). For example, the rate at which sight deflection ***Ls*** is changing is expressed by the symbol ***DLs***, and the rate at which sight angle ***Vsd*** is changing is expressed by the symbol ***DVsd***.

Offsets to Future, Advance, and Aiming Positions

The offsets to the future, advance, and aiming positions are expressed as:

1. The angular portions of sight angles and sight deflections measured to these positions, and
2. The linear displacements of these positions from the line of sight.

Angular offsets. Besides expressing total sight angles and sight deflections, and the individual portions of these offsets accounting for specific factors, the parts of sight angles and sight deflections measured to the future and advance positions are symbolized.

To symbolize the portion of sight angle or sight deflection measured to the future position, the symbol for the total angle is enclosed in parentheses and preceded by the quantity modifier ***m***. For example, the portion of sight deflection ***Ls*** measured to the future target position is symbolized as ***m***(***Ls***), and the portion of sight angle ***Vsd*** is symbolized ***m***(***Vsd***). This device is the same as used to indicate the portion of sight angle and sight deflection accounting for relative motion given under "Individual offsets" in this section. This symbolization has been selected because the location of the future target position is determined solely from target motion during the time of flight.

To symbolize the portion of sight angle and sight deflection measured to the advance position, the symbol for the total angle is enclosed in parentheses and preceded by the quantity modifier ***a***. For example, the portion of sight deflection ***Lsd*** measured to the advance position is symbolized as ***a***(***Lsd***), and the portion of sight angle ***Vs*** measured to the advance position is symbolized as ***a***(***Vs***).

Symbols for offsets to the aiming position are the symbols for the total lead angles themselves. That is, the symbols for sight angles and sight deflections.

Linear offsets. The class of quantities expressing linear displacements to the future target position is represented by the basic symbol ***M***. Useful components of ***M*** are defined, illustrated, and symbolized in "Linear Motion" under "Motion" in this section.

The class of quantities expressing linear displacements to the advance and aiming positions is represented by the basic symbol ***M*** followed by the numeral modifier ***3*** for advance position, forming symbol ***M3***, and by numeral modifier ***4*** for aiming position, forming symbol ***M4***. Useful components of ***M3*** and ***M4*** are defined, illustrated, and symbolized in "Linear Motion" under "Motion" in this section.

Coordinates of Future, Advance, and Aiming Positions

The measurements to determine the locations of the future, advance, and aiming positions are made in the same reference frames and by the same types of coordinate systems as used to determine present target position. That is, the positions are located in a reference frame originating on own ship (reference point) by means of spherical, cylindrical, or cartesian coordinates.

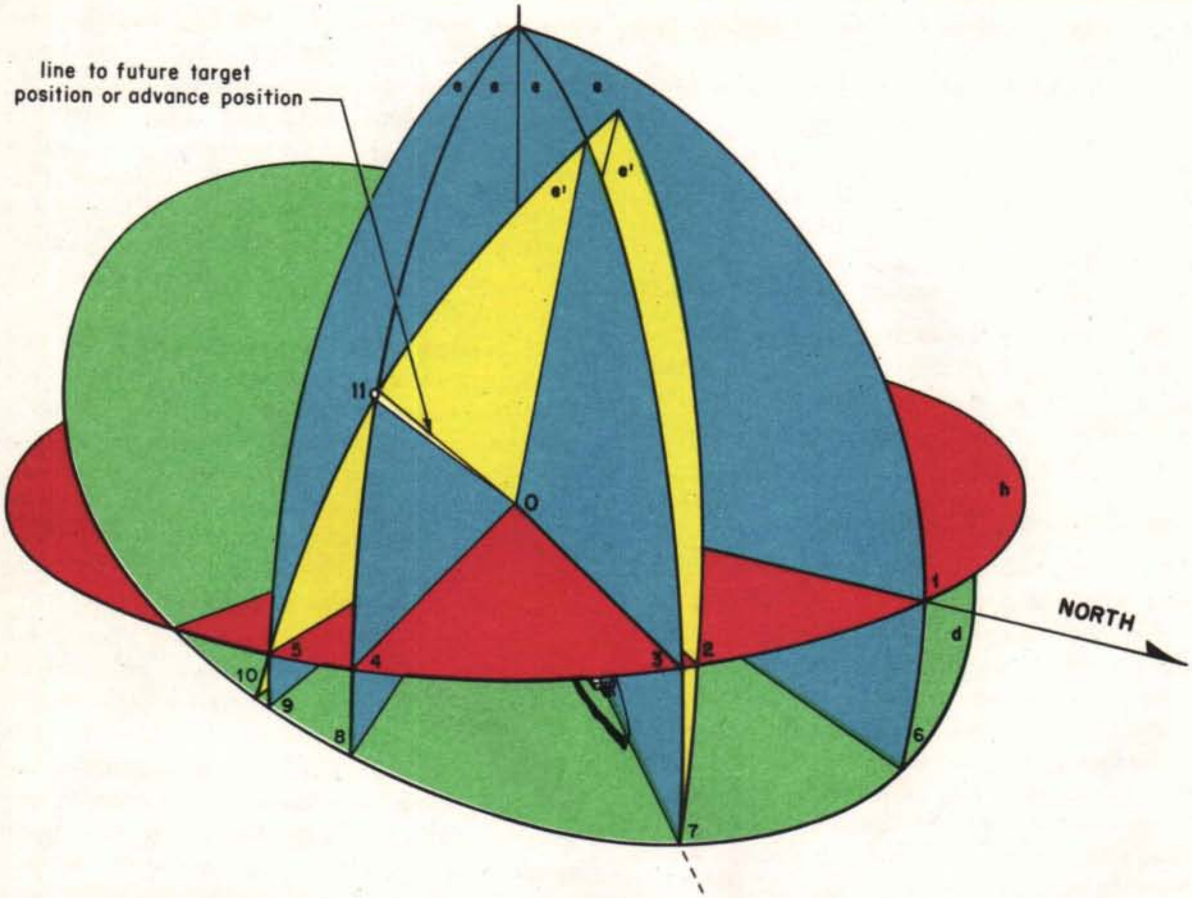

Figure 28.—Angular Coordinates of Future and Advance Positions.

Reference planes used for measurements are:

1. Horizontal plane.
2. Deck plane.

Reference lines used are:

1. Vertical.
2. Normal.
3. Own ship centerline.
4. N–S line.

The classes of quantities expressing the future, advance, and aiming positions are the same as those used to express present target position. That is, Bearings (***B***), Elevations (***E***), and Ranges (***R***). To denote measurements of these quantities to the various positions, numeral modifiers are used. Numeral ***2*** signifies future target position, ***3*** advance position, and ***4*** aiming position.

Future position. To express future position in the various coordinate systems, symbols for the same quantities used to express present target position are terminated by numeral modifier ***2***. For example, for present target position coordinates ***Bd′***, ***Ed′***, and ***R***, the corresponding coordinates for future target position are ***Bd2′***, ***Ed2′***, and ***R2***.

Advance position. To express advance position in the various coordinate systems, symbols for the same quantities used to express present target position are terminated by numeral modifier ***3***. For example, for present target position coordinates ***By***, ***Rh***, and ***Rv***, the corresponding coordinates for advance position are ***By3***, ***Rh3***, and ***Rv3***.

Aiming position. To express aiming position in the various coordinate systems, symbols for range and range components of present target position are terminated by numeral modifier ***4***. Symbols for bearing and elevation quantities are terminated by modifier ***g***, since these are the angular measurements to the line of fire.

TABLES FOR FIGURE 28

Table 28A

			To vertical plane through line to future target position	To normal plane through line to future target position	To vertical plane through line to advance position	To normal plane through line to advance position
Bearing	In horizontal plane	From N–S vertical plane	***By2*** [1–4]	***By2′*** [1–5]	***By3*** [1–4]	***By3′*** [1–5]
		From vertical plane through OS CL	***B2*** [3–4]	***B2′*** [3–5]	***B3*** [3–4]	***B3′*** [3–5]
	In deck plane	From N–S vertical plane	***Bdy2*** [6–8]	***Bdy2′*** [6–10]	***Bdy3*** [6–8]	***Bdy3′*** [6–10]
		From vertical plane through OS CL	***Bd2*** [7–8]	***Bd2′*** [7–10]	***Bd3*** [7–8]	***Bd3′*** [7–10]

Table 28B

		In vertical plane through line to future target position	In normal plane through line to future target position	In vertical plane through line to advance position	In normal plane through line to advance position
Elevation	From horizontal plane	***E2*** [4–11]	***E2′*** [5–11]	***E3*** [4–11]	***E3′*** [5–11]
	From deck plane	***Ed2*** [8–11]	***Ed2′*** [10–11]	***Ed3*** [8–11]	***Ed3′*** [10–11]

For example, for present target position coordinates ***B***, ***E***, and ***R***, the corresponding coordinates for aiming position are ***Bg***, ***Eg***, and ***R4***.

In figure 28, bearing and elevation angles used to express the location of the future and advance positions in any of the coordinate systems are shown with numerals indicating the arc measuring each angle.

In figure 29, range and range components expressing future and advance positions in any of the coordinate systems are shown with numerals indicating the distances. In composite tables 28A, 28B, and 29 each bearing, elevation, and range component of future and advance positions is defined and symbolized.

For example, in figure 28, bearing of the future and advance position from the N–S vertical plane to the vertical plane through the line to these positions measured in the horizontal plane is illustrated as the angle —1–4. In composite table 28A, this angle is defined and symbolized ***By2*** for future target position, and defined and symbolized ***By3*** for advance position.

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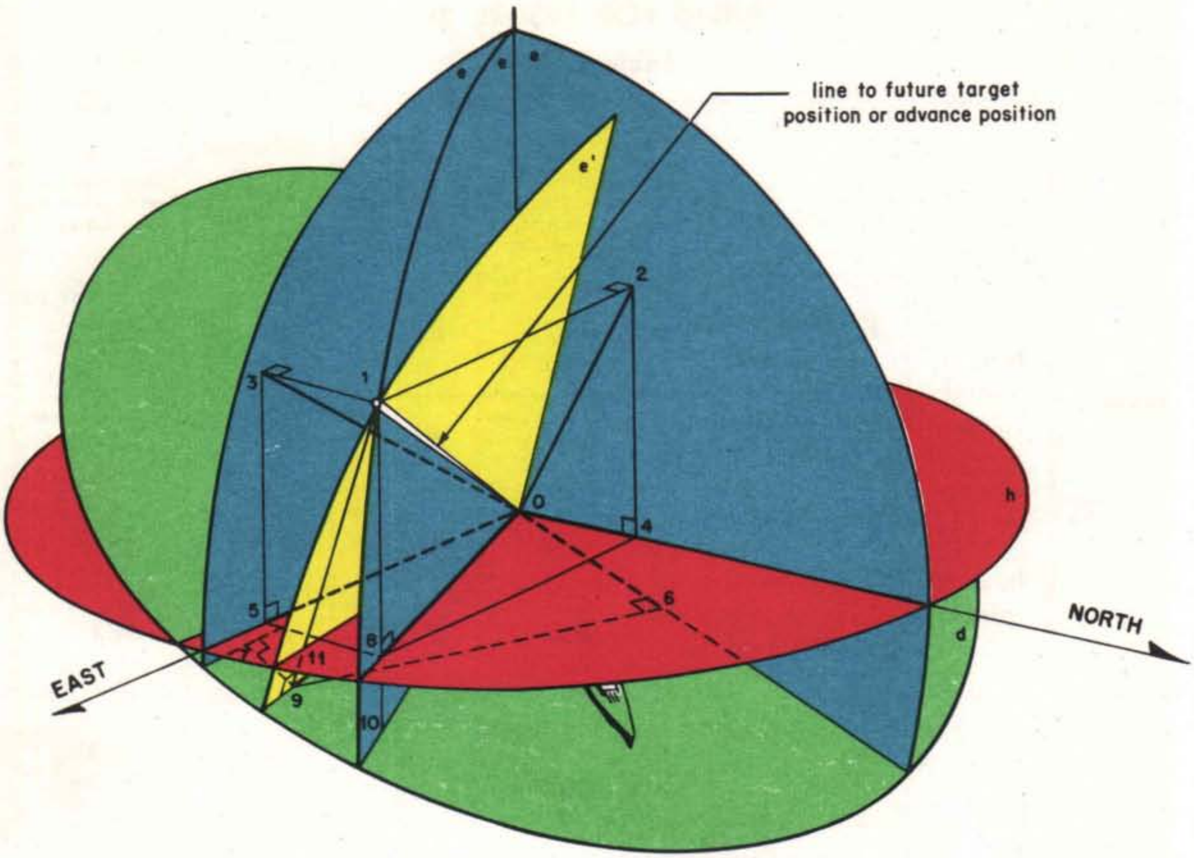

Figure 29.—Ranges and Heights of Future and Advance Positions.

Coordinates of the aiming position are not shown here since the bearings and elevations of this position are the orders positioning the gun along the line of fire. These coordinates are defined, illustrated, and symbolized in figure 30 under "Gun Orders" in this section.

Range predictions. In determining the coordinates of future target position and advance position, the differences in range between the present target position and the future target and advance positions are computed to obtain the range coordinates.

The difference in range between the present target position and the advance position is called "range prediction," and is symbolized by following the basic range symbol ***R*** with modifiers ***p*** and numeral ***3***, forming symbol ***Rp3.***

The individual parts of range prediction to the advance position are:

1. Difference in range between present and future target positions,
2. Correction to present range accounting for wind effect, and
3. Correction to present range accounting for initial velocity loss.

The difference in range between present and future target positions is symbolized ***Rp2.*** The corrections to present range accounting for wind and changes in initial velocity are symbolized by enclosing the range prediction symbol ***Rp3*** in parentheses and preceding the parentheses with quantity modifier ***w*** for wind, forming symbol ***w***(***Rp3***), and quantity modifier ***u*** for initial velocity loss, forming symbol ***u***(***Rp3***). Thus, ***Rp3***=***Rp2***+***u*** (***Rp3***)+***w*** (***Rp3***).

In figure 23, range predictions to the future target position and to the advance position are illustrated and symbolized.

TABLE FOR FIGURE 29

					N–S components	E–W components
Range	Along line to future target position			***R2*** 0–1	***Ry2*** 0–2	***Rx2*** 0–3
	Along line to advance position			***R3*** 0–1	***Ry3*** 0–2	***Rx3*** 0–3
	Along inter-section of	Vertical plane through line to future target position	And horizontal	***Rh2*** 0–8	***Rhy2*** 0–4	***Rhx2*** 0–5
		Normal plane through line to future target position	And deck	***Rd2*** 0–9	***Rdy2*** 0–6	***Rdx2*** 0–7
		Vertical plane through line to advance position	And horizontal	***Rh3*** 0–8	***Rhy3*** 0–4	***Rhx3*** 0–5
		Normal plane through line to advance position	And deck	***Rd3*** 0–9	***Rdy3*** 0–6	***Rdx3*** 0–7

Height		Of future target position		Of advance position	
		In vertical plane through line to future target position	In normal plane through line to future target position	In vertical plane through line to advance position	In normal plane through line to advance position
	Above horizontal	***Rv2*** 8–1	***Rv2'*** 11–1	***Rv3*** 8–1	***Rv3'*** 11–1
	Above deck	***Rvd2*** 10–1	***Rvd2'*** 9–1	***Rvd3*** 10–1	***Rvd3'*** 9–1

Fuze range. In the computation of fuze settings an additional range value called "fuze range" is determined. To express fuze range, basic range symbol ***R*** is terminated by numeral **5,** forming symbol ***R5.***

Fuze range ***R5*** is composed of:

1. Advance range, and
2. Change in advance range during dead time.

Advance range is symbolized ***R3*** (see "advance position" in this section). To express the change in advance range during dead time, symbol ***R3*** for advance range is enclosed in parentheses and preceded by quantity modifier ***g,*** forming symbol ***g***(***R3***).

Thus ***R3***+***g***(***R3***)=***R5*** means advance range plus change in advance range during dead time equals fuze range.

ANTIAIRCRAFT RELATED QUANTITIES

Chapter 5—Gun Orders

Contents

Chapter 5

GUN ORDERS

Gun orders are the computed angular values used to position the gun along the line of fire. Since the location of the line of fire is expressed by angular coordinates of the aiming position (that is, the position through which the line of fire passes), consideration is first given to the quantities expressing this position.

Coordinates of Aiming Position

As stated in "Coordinates of future, advance, and aiming positions" under "Linear and Angular Offsets" in this part, the references and the systems of coordinates used to measure the location of the aiming position are the same as those used to measure the location of present target position. The construction of symbols for the quantities expressing this position in any of the coordinate systems is discussed in "Aiming position" under "Linear and Angular Offsets" in this part.

Figure 30 shows the bearing and elevation angles used to express the location of the aiming position in any of the coordinate systems with numerals to indicate the arc measuring each angle. In composite table 30A each bearing angle is defined and symbolized, and in composite table 30B each elevation angle is defined and symbolized.

Figure 31 shows range and range components used to express the location of the aiming position in any of the coordinate systems with numerals to indicate the distances. In composite table 31 each range component is defined and symbolized.

For example, in figure 31, the total range to the aiming position measured along the line of fire is illustrated as the distance 0–1. In composite table 31, this distance is defined and symbolized ***R4***.

Since the line of fire passes through the aiming position, the bearing and elevation angles of this point are used to position the gun along the line of fire, and are called "gun orders."

The class of quantities measured in the horizontal and deck planes, that is, the bearings, are called "gun trains," and the class of quantities measured in vertical or normal planes, that is, the elevations, are called "gun elevations."

Gun trains. The class of quantities expressing gun trains is indicated by the symbol ***B*** followed by modifier ***g***, forming ***Bg***, appearing in the symbol. In the expression of gun orders, gun train angles measured in the horizontal plane are called "gun bearings," and gun train angles measured in the deck plane are called "gun trains." When the general term "gun trains" is used in this text it includes both types of quantities.

The basic gun train quantity (represented by symbol ***Bg***) is the angle between the vertical plane through own ship centerline and the vertical plane through the line of fire measured in the horizontal plane. (See figure 30 and table 30A.)

To express gun train between own ship centerline and the vertical plane through the line of fire measured in the deck plane, modifier ***d*** is added before modifier ***g*** in the basic symbol ***Bg***, forming symbol ***Bdg***. (See figure 30 and table 30A.)

When gun train angles are measured in other ways, modifiers are applied to ***Bg*** or ***Bdg*** in the order listed as follows:

Modifier	Measured
y	From north.
'	To normal plane through line of fire.

As stated under "Coordinates of Advance Position" in this part, gun train angles are illustrated in figure 30, and defined and symbolized in composite table 30A.

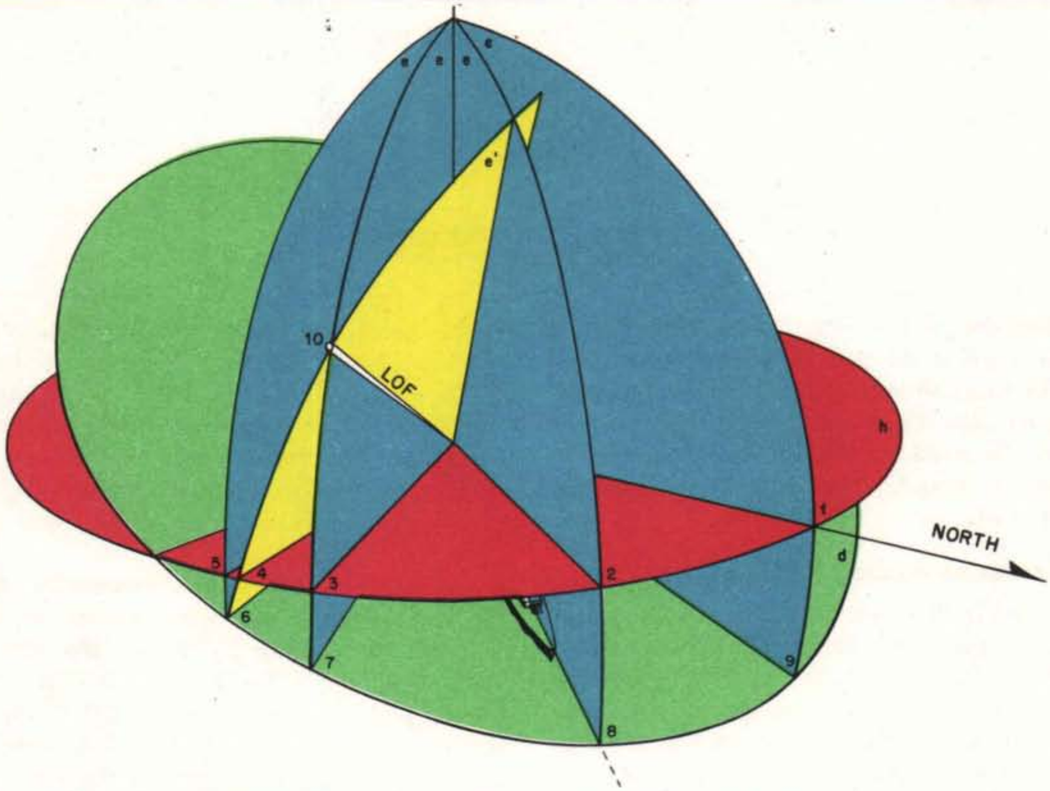

Figure 30.—Angular Coordinates of Aiming Position.

For example, gun train angle measured from the vertical plane through own ship centerline to the normal plane through the line of fire in the deck plane is illustrated as the angle 8–6. In composite table 30A, this angle is defined and symbolized ***Bdg'***.

Gun elevations. The class of quantities expressing gun elevations is indicated by the symbol ***E*** followed by modifier ***g***, forming symbol ***Eg***, appearing in the symbol.

The basic gun elevation quantity (represented by symbol ***Eg***) is the angle measured from the horizontal plane to the line of fire in the vertical plane through the line of fire. (See figure 30 and table 30B.)

To express gun elevation measured from the deck plane to the line of fire in the vertical plane through the line of fire, modifier ***d*** is added before modifier ***g*** in the basic symbol ***Eg***, forming symbol ***Edg***. (See figure 30 and composite table 30B.)

To indicate measurements of gun elevations ***Eg*** and ***Edg*** in the normal plane through the line of fire, instead of the vertical plane, a ***'*** (prime) modifier is added at the end of the symbol.

As stated under "Coordinates of Advance Position" in this part, gun elevation angles are illustrated in figure 30, and defined and symbolized in composite table 30B.

For example, gun elevation measured from the deck plane to the line of fire in the normal plane through the line of fire is illustrated as the angle 6–10. In composite table 30B, this angle is defined and symbolized ***Edg'***.

The gun train angle ***Bdg'*** and the gun elevation angle ***Edg'*** are called "gun train order" and "gun elevation order," respectively, since these are the final angles computed by all present naval fire control equipments for positioning a gun along the line of fire.

Coordinate Transformation

Geometrical quantities closely associated with gun order values are quantities expressing:

1. Inclination of the deck plane with respect to the horizontal plane related to the line of fire, and

TABLES FOR FIGURE 30

Table 30A

			To vertical plane through LOF	To normal plane through LOF
Gun train	In horizontal plane	From vertical plane through OS CL	***Bg*** 2–3	***Bg′*** 2–4
		From N–S vertical plane	***Bgy*** 1–3	***Bgy′*** 1–4
	In deck plane	From vertical plane through OS CL	***Bdg*** 8–7	***Bdg′*** 8–6
		From N–S vertical plane	***Bdgy*** 9–7	***Bdgy′*** 9–6

Table 30B

		In vertical plane through LOF	In normal plane through LOF
Gun elevation	From horizontal plane	***Eg*** 3–10	***Eg′*** 4–10
	From deck plane	***Edg*** 7–10	***Edg′*** 6–10

Table 30C

	In vertical plane through LOF	In normal plane through LOF
Level angle between horizontal and deck planes	***Eig*** 3–7	***Eig′*** 4–6

Rotation about line of fire about axis 10 ***Zg***

Rotation about axis in the deck plane about axis 6 Trunnion tilt—***Zdg′***

2. Displacements between reference point and gun, and corrections to values computed at the reference point to account for this displacement.

The planes and lines used to express these quantities are essentially the same as those used with gun order values.

Deck inclination. In disturbed line of sight systems, inclination of the deck plane with respect to the horizontal plane is measured by level and cross-level angles related to the line of fire. The measurement of these angles is essentially the same as the measurement of level and cross-level angles related to the line of sight.

Level and cross-level quantities measured

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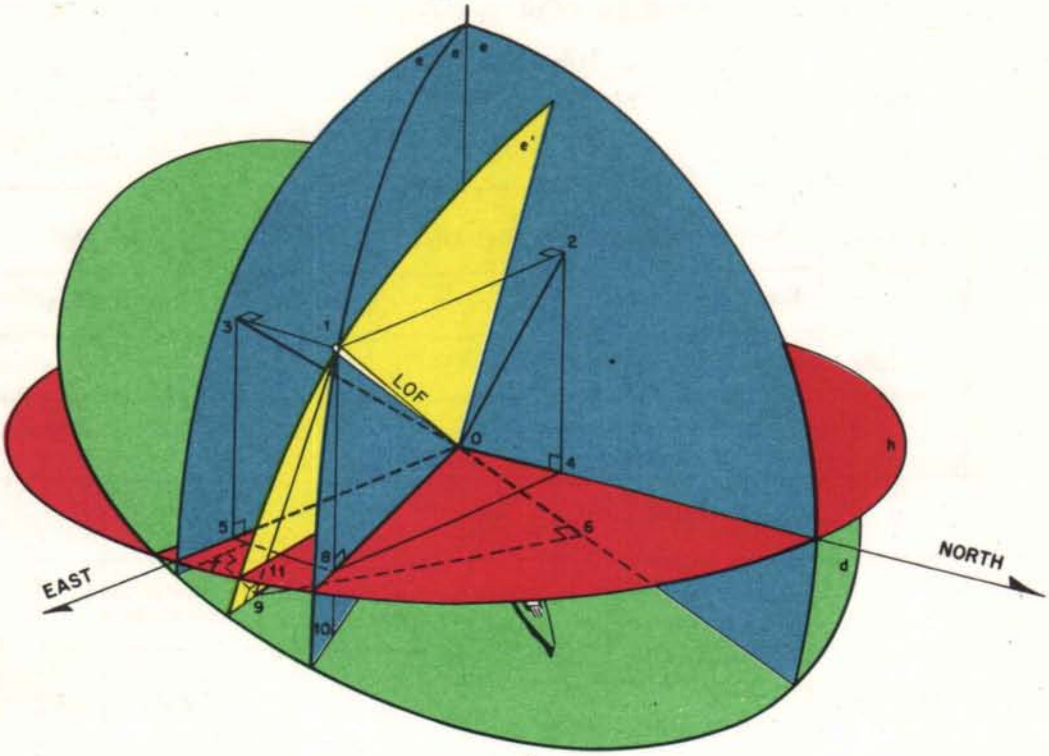

Figure 31.—Ranges and Heights of Aiming Position.

TABLE FOR FIGURE 31

					N–S component	E–W component
Aiming range	Along LOF			***R4*** 0–1	***Ry4*** 0–2	***Rx4*** 0–3
	Along inter-section of	Vertical plane through LOF and	Horizontal	***Rh4*** 0–8	***Rhy4*** 0–4	***Rhx4*** 0–5
		Normal plane through LOF and	Deck	***Rd4*** 0–9	***Rdy4*** 0–6	***Rdx4*** 0–7

Height of aiming position	In vertical plane through LOF	Above horizontal	***Rv4*** 8–1
		Above deck	***Rvd4*** 10–1
	In normal plane through LOF	Above horizontal	***Rv4'*** 11–1
		Above deck	***Rvd4'*** 9–1

about the line of fire are illustrated in figure 30. The angles are defined and symbolized in composite table 30C. For example, cross-level angle measured between a vertical and normal plane, about an axis which is the intersection of the normal plane through the line of fire and the deck plane is illustrated as the angle measured about axis 6. In composite table 30C, this angle is symbolized ***Zdg'***.

Only those level and cross-level angles which have proved of value are illustrated in figure 30; however, to symbolize any level or cross-level angle measured about the line of fire, the corresponding angle measured about the line of sight is terminated by modifier ***g***. Level and cross-level angles measured about the line of sight are discussed, defined, and symbolized under "Present Target Position" in this section. They are illustrated in figure 1.

Gun parallax. In solving the gun fire control problem, measurements made from the reference point are used to compute gun orders. After the gun orders are computed, they are corrected for parallax resulting from displacement of the gun from the reference point. The gun parallax corrections for displacement between gun and reference point are separated into two groups as follows:

1. Dynamic gun parallax corrections.
2. Static gun parallax corrections.

DYNAMIC GUN PARALLAX. Gun orders computed for the reference point are correct only for a gun located exactly at the reference point. Dynamic differences result because the motion of the gun is different from the motion of the reference point because of the rolling and pitching of the ship. Therefore, the advance position of the gun is different from that of the reference point. These dynamic factors are usually negligible and are not corrected for in present naval gun fire control systems. However, symbols to express these dynamic corrections are given.

Dynamic gun parallax corrections. To symbolize the total rate of relative motion between target and gun, symbol ***DM*** for total rate of relative motion between reference director and target is enclosed in parentheses and followed by quantity modifier ***p***, forming symbol (***DM***)***p***.

To express the additional rate of the gun with respect to the reference director due to the rolling and pitching of the ship, symbol ***DM*** is enclosed in parentheses and preceded by quantity modifier ***p***, forming symbol ***p***(***DM***).

Thus, ***DM***+***p***(***DM***)=(***DM***)***p*** means total rate of relative motion between reference director and target plus rate of gun with respect to reference director equals total rate of relative motion between target and gun.

To express components of (***DM***)***p*** and ***p***(***DM***) measured in various directions, symbol for same component of ***DM*** is enclosed in parentheses and preceded or followed by quantity modifier ***p*** as required. ***DM*** and components of ***DM*** are discussed, defined, symbolized, and illustrated in "Linear Motions" under "Motion" in this part.

For example, to express the rate of relative motion between target and gun measured along the line of sight, symbol ***DMr*** for the same component of ***DM*** is enclosed in parentheses and followed by ***p***, forming symbol (***DMr***)***p***. To express the rate of the gun with respect to the reference director measured along the line of sight, symbol ***DMr*** is enclosed in parentheses and preceded by ***p***, forming symbol ***p***(***DMr***).

Thus ***DMr***+***p***(***DMr***)=(***DMr***)***p*** means rate of relative motion between target and reference director along line of sight plus rate of gun with respect to reference director along line of sight equals rate of relative motion between target and gun along line of sight.

STATIC GUN PARALLAX. The angular values and linear distances computed for a gun located at the reference point require corrections when used for a gun displaced from the reference point.

The corrections to the gun order quantities computed for the reference point are obtained by using as one of the values in the formula a component of the linear distance between the reference point and the gun (gun parallax displacement). For example, in computing gun train order for a displaced gun, the value of the projection of gun parallax displacement in the deck plane is required as one of the terms in the formula.

Gun parallax displacements. The class of quantities expressing linear displacements between gun and reference point is called "gun

TABLE FOR FIGURE 32

					N–S component	E–W component
Gun parallax displacement	Along base line from reference point to gun			***P*** 0-1	***Py*** 0-2	***Px*** 0-3
	Along intersection	Vertical plane through base line and	Horizontal	***Ph*** 0-8	***Phy*** 0-4	***Phx*** 0-5
		Normal plane through base line and	Deck	***Pd*** 0-9	***Pdy*** 0-6	***Pdx*** 0-7
	In vertical plane through base line		Above horizontal	***Pv*** 8-1		
			Above deck	***Pvd*** 10-1		
	In normal plane through base line		Above horizontal	***Pv′*** 11-1		
			Above deck	***Pvd′*** 9-1		

TABLE FOR FIGURE 33

Gun parallax displacement along intersection of	Vertical plane through OS CL	And horizontal	***Pho*** 0-4
	Normal plane through OS CL	And deck	***Pdo*** 0-5
	Vertical plane perpendicular to vertical plane through OS CL	And horizontal	***Pha*** 0-2
	Normal plane perpendicular to normal plane through OS CL	And deck	***Pda*** 0-3

parallax displacements," and is represented by basic symbol ***P***.

The basic gun parallax displacement quantity (symbolized by basic symbol ***P***) is the linear distance between gun and reference point measured along the gun parallax base line. (See figure 32 and table 32.)

Components of gun parallax displacement are expressed by applying modifiers to the basic symbol ***P***. These components are separated into three groups—horizontal and deck components, N–S and E–W components, and vertical components.

Horizontal and Deck Components: To express horizontal and deck components of gun parallax displacement, modifiers are applied to ***P*** in the order listed as follows:

Modifier **Measured**

h---------- In horizontal.
d---------- In deck.
o---------- Along own ship centerline.
a---------- Athwartship, normal to own ship centerline.

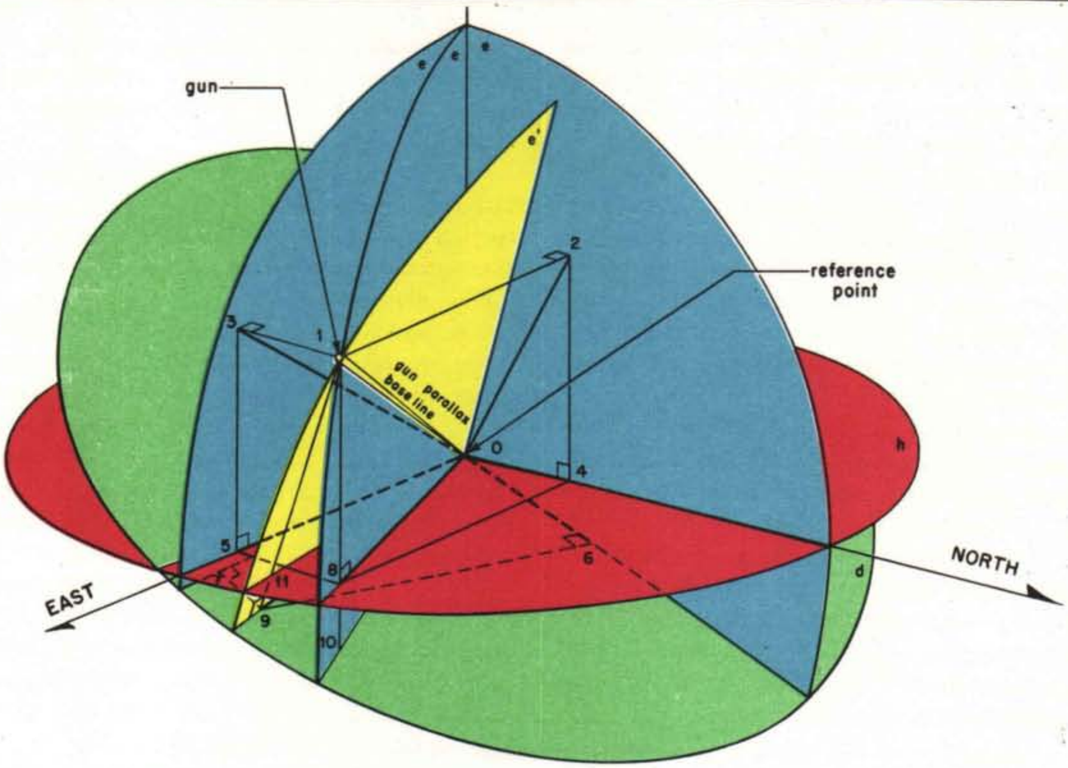

Figure 32.—North-South and East-West Gun Parallax Displacements.

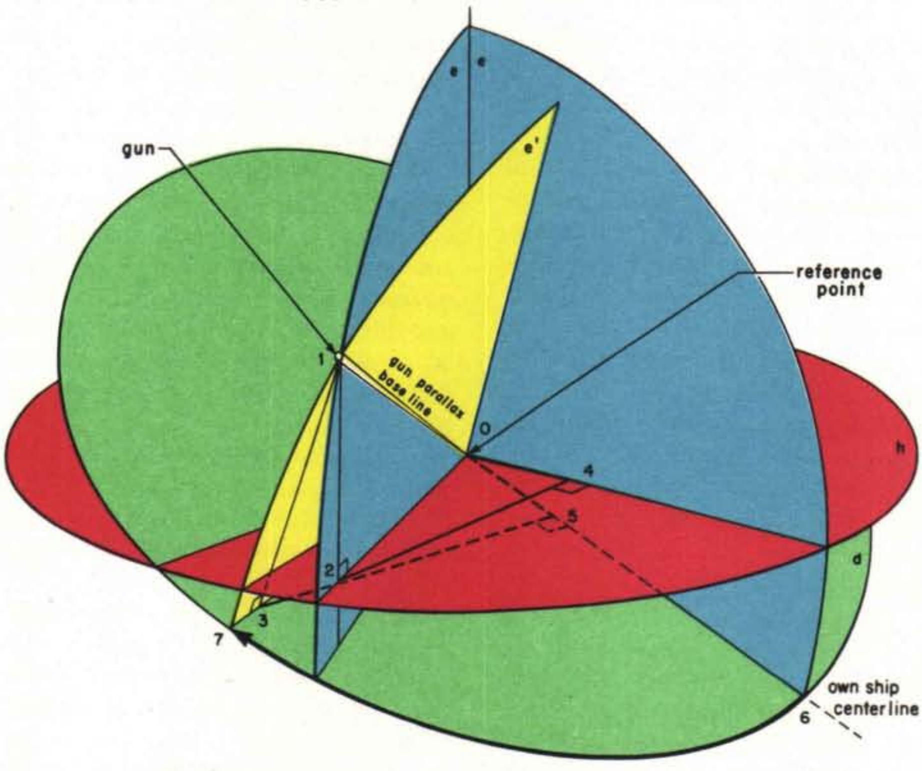

Figure 33.—Gun Parallax Displacements.

When only modifier ***h*** accompanies the symbol (that is, ***Ph***), the quantity is the projection of ***P*** in the horizontal plane; when only modifier ***d*** accompanies the symbol (that is ***Pd***), the quantity is the projection of ***P*** in the deck plane.

Quantities ***Pho*** and ***Pha*** are the components along and across the vertical plane through own ship centerline, and quantities ***Pdo*** and ***Pda*** are the components of deck projection ***Pd*** along and across own ship centerline. (See figure 33 and table 33.)

North-South and East-West Components: Projections of ***P, Ph,*** and ***Pd*** are expressed by adding modifier ***y*** for N–S projection, and ***x*** for E–W projections.

Vertical Components: Basic symbol ***P*** is modified by ***v*** to express the general quantity indicating vertical parallax displacement. To express vertical gun parallax displacement components, modifiers are applied to ***Pv*** in the order listed as follows:

Modifier	Measured
d	From deck.
	In normal plane.

When no prime appears, vertical component is measured in a vertical plane; when no ***d*** appears, vertical component is measured from the horizontal plane.

Figures 32 and 33 show all components of gun parallax displacement required in computing corrections to reference point gun orders. Figure 32 shows the horizontal and deck projections, N–S and E–W projections, and the vertical components. Figure 33 shows the components along and across own ship centerline. In composite tables 32 and 33, each gun displacement quantity is defined, and symbolized. For example, in figure 32, the projection of gun parallax displacement in the horizontal plane is illustrated as the distance 0–8. In composite table 32, this distance is defined and symbolized ***Ph***.

Gun Parallax Angle: To express the angle measured in the deck plane about the reference point, between the normal plane through the gun parallax base line and own ship centerline, or if reference point is displaced from centerline, the line in the deck plane through the reference point parallel to own ship centerline, basic bearing symbol ***B*** is modified by ***o*** and ***g***, forming symbol ***Bog***. In figure 33, this quantity is illustrated as the angle 6–7.

Correction quantities. As stated in the introduction to "Static Gun Parallax," the correction quantities used in converting gun orders computed for the reference point to gun orders for a displaced gun are obtained by using components of gun parallax displacement.

To express the parallax correction to gun order quantities computed for the reference point to obtain gun order quantities for the displaced gun, the symbol for the quantity computed for the references point is enclosed in parentheses and preceded by quantity modifier ***p***. For example, to obtain gun train order for a displaced gun, the correction applied to gun train order computed for the reference point ***Bdg′*** is symbolized ***p(Bdg′)***.

To express gun train order for the displaced gun, gun train order as computed for the reference point ***Bdg′*** is enclosed in parentheses and followed by quantity modifier ***p***, forming symbol ***(Bdg′)p***.

Thus, ***Bdg′+p(Bdg′)=(Bdg′)p*** means gun train order computed for the reference point plus parallax corrections to reference point gun train order accounting for gun displacement equals gun train order for displaced gun.

In some naval fire control systems, parallax corrections are computed to gun train order for a standard gun base length, and the individual guns select the portion of that base length correction they require. This standard base length correction is called "unit parallax," and is usually computed for a one hundred yard deck displacement forward of the reference point.

To symbolize unit parallax, gun train order for the reference point ***Bdg′*** is enclosed in parentheses and preceded by quantity modifiers ***p*** and numeral ***1***, forming symbol ***p1(Bdg′)***.

In some naval fire control equipments, the computation of the parallax correction to reference point gun elevation order to obtain gun elevation order for a displaced gun is made by:

1. Computing a correction for displacement in the deck plane, and

2. Computing a correction for a vertical displacement,

and combining these two corrections to obtain the total correction.

To symbolize the correction to reference point gun elevation order to account for a displacement in the deck plane, total correction ***p*(*Edg′*)** is terminated by modifier ***h***, forming symbol ***p*(*Edg′*)*h***.

In some equipments, ***p*(*Edg′*)*h*** is computed for a standard parallax base length, usually a one hundred yard deck displacement. To symbolize this quantity when computed for the standard base length, numeral modifier ***1*** is added after modifier ***p***, forming symbol ***p1*(*Edg′*)*h***.

To symbolize the correction to reference point gun elevation order to account for a vertical displacement, total correction ***p*(*Edg′*)** is terminated by modifier ***v***, forming symbol ***p*(*Edg′*)*v***.

In some equipments, ***p*(*Edg′*)*v*** is computed for a standard parallax base length, usually a ten yard vertical displacement. To symbolize this quantity when computed for the standard base length, numeral modifier ***1*** is added after modifier ***p***, forming symbol ***p1*(*Edg′*)*v***.

Thus ***p*(*Edg′*)*h*+*p*(*Edg′*)*v*=*p*(*Edg′*)** means the correction to reference point gun elevation order for a deck displacement plus the correction for a vertical displacement equals the total correction to reference point gun elevation order to obtain gun elevation order for the displaced gun.

Symbolization Problems

This part of the book is established as a reference for gun order quantities whose symbolization is made difficult by the way in which the fire control instrument combines quantities. That is, it is provided to establish and maintain standard symbols for quantities whose symbols may be constructed in more than one way.

One such quantity is the gun train order used in Gun Fire Control System Mk 63 to obtain predicted true wind angle. However, since the computations are concerned with obtaining wind quantities, the symbolization problem is discussed under wind symbolization problems.

DICTIONARY OF SYMBOLS

Introduction

This section lists alphabetically, defines, and illustrates most symbols for naval fire control quantities. The listing includes symbols formulated in this pamphlet (indicated in heavy **BOLD** type) and referred to as "standard" symbols, and symbols listed in OD 3447, Standard Fire Control and Torpedo Control Symbols (indicated in lighter-weight ***bold*** type) and referred to as "previous" symbols.

Each standard symbol is defined and illustrated, and makes note of any previous symbol used to represent the quantity. For example, the definition of the standard symbol for gun train order, ***Bdg'***, is followed by a note stating that the previous symbol is *B'gr*.

A previous symbol is neither defined nor illustrated, but is listed with a reference to the standard symbol which represents the same quantity. For example, the listing of the previous symbol for gun elevation order, *E'g*, includes no definition but makes reference to the standard symbol, ***Edg'***.

A previous symbol used to represent one quantity, but in this pamphlet used as a standard symbol to represent a different quantity, is listed with a reference to the name of the quantity it formerly represented. For example, standard symbol ***A*** is defined as the difference in elevation between present and future target positions. Its listing is followed by a note stating that it previously was used to represent target angle, and that target angle is now expressed by standard symbol ***Bot.***

One definition is used for each group of similar quantities included: (1) linear rates and movements of own ship and target, (2) wind rates, (3) wind angles, and (4) wind courses. Each definition is listed with a standard symbol representing one of the similar quantities, and is followed by a note giving the standard symbols and names for similar quantities remaining. The listing also contains the standard symbols for the similar quantities remaining, with references to the standard symbols defined. For example, ***Bwy*** is defined as true direction true wind. This definition also covers ***Bwyo,*** true direction own ship wind, and ***Bwya,*** true direction apparent wind—symbols which are noted in the listing of ***Bwy***. ***Bwyo*** and ***Bwya*** appear also in the listing, with a reference to ***Bwy.***

Standard symbols for linear rates of own ship and target are not listed, as they are obtained by prefixing ***D*** (standard symbol for time rate of change) to the standard symbols for the resulting linear movements. For example, rate of relative motion in range between own ship and target, ***DMr,*** is not listed, but is obtained by prefixing ***D*** to ***Mr,*** the resulting relative linear movement in range during time of flight.

Standard symbols formed by applying quantity modifiers to parentheses which enclose standard symbols are not listed, as the quantity modifiers are listed in Appendix C and the enclosed standard symbols are included in the listing. For example, ***m***(***Ls***) is not included in the listing, but ***m*** is listed and defined in the first part of this pamphlet, and ***Ls*** is included and defined in the listing. A previous symbol representing a quantity now represented by a standard symbol containing a quantity modifier is defined because the standard symbol for the quantity is not listed. Therefore, the definition for the previous symbol is followed by a note giving the standard symbol. For example, the standard symbol for the part of sight angle accounting for relative motion between own ship and target, ***m***(***Vs***), is not included in the listing, but previous symbol for this quantity, ***Vt,*** is included. Therefore, the definition is given under the listing of ***Vt,*** followed by a note stating that ***m***(***Vs***) is the standard symbol for the quantity defined.

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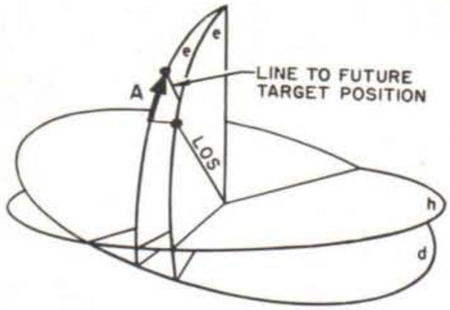
A

Relative Angular Movement in Elevation

The difference in elevation from the horizontal plane between the present line of sight and the line to the future target position, measured upward to the line to the future target position in a vertical plane.

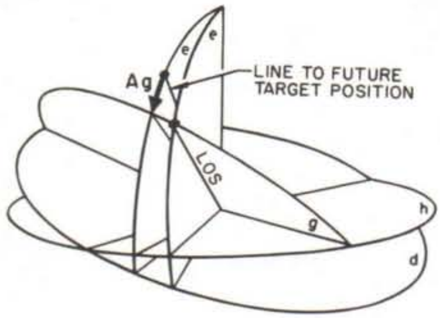
Note: 1. Previously used for target angle. See ***Bot***



Ag

Relative Angular Movement in Elevation

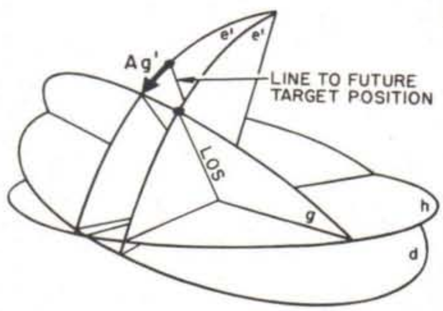
Angle between the line to the future target position, and the slant plane through the line of sight and through the gun elevation axis in the horizontal plane, measured from the line to the future target position in the vertical plane through the line to the future target position.



Ag′

Relative Angular Movement in Elevation

Angle between the line to the future target position, and the slant plane through the line of sight and through the gun elevation axis in the horizontal plane, measured from the line to the future target position in the normal plane through the line to the future target position.



Agd

Relative Angular Movement in Elevation

Angle between the line to the future target position, and the slant plane through the line of sight and through the gun elevation axis in the deck plane, measured from the line to the future target position in the vertical plane through the line to the future target position.

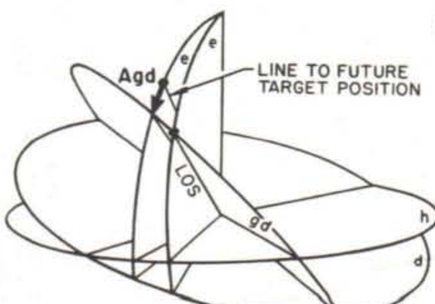
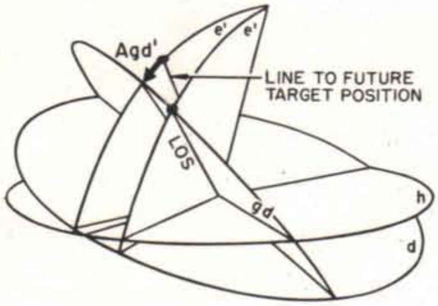


Table of Contents

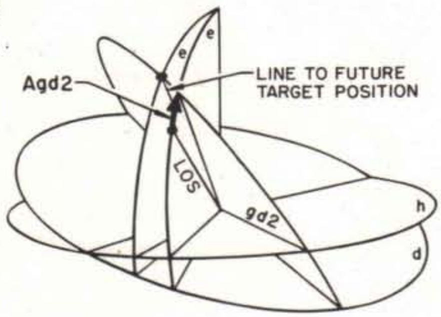
Agd'



Relative Angular Movement in Elevation

Angle between the line to the future target position, and the slant plane through the line of sight and through the gun elevation axis in the deck plane, measured from the line to the future target position in the normal plane through the line to the future target position.

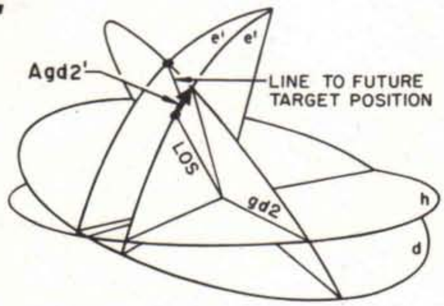
Agd2



Relative Angular Movement in Elevation

Angle between the line of sight, and the slant plane through the line to the future target position and through the gun elevation axis in the deck, measured from the line of sight in the vertical plane through the line of sight.

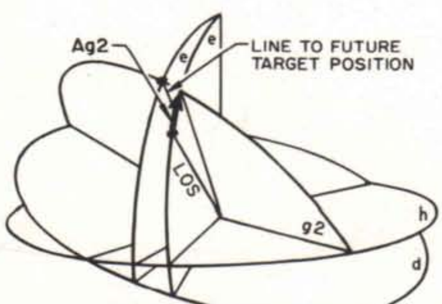
Agd2'



Relative Angular Movement in Elevation

Angle between the line of sight, and the slant plane through the line to the future target position, and through the gun elevation axis in the deck, measured from the line of sight in the normal plane through the line of sight.

Ag2



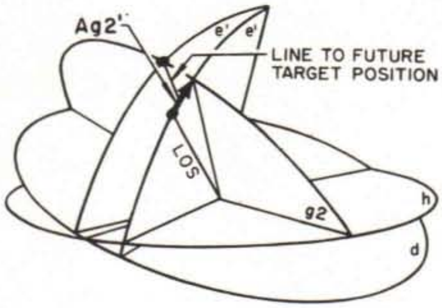
Relative Angular Movement in Elevation

Angle between the line of sight, and the slant plane through the line to the future target position and through the gun elevation axis in the horizontal, measured from the line of sight in the vertical plane through the line of sight.

Ag2'

Relative Angular Movement in Elevation

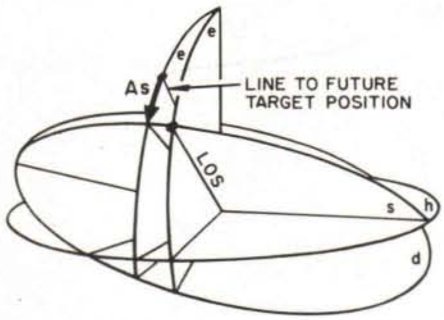
Angle between the line of sight, and the slant plane through the line to the future target position and through the gun elevation axis in the horizontal, measured from the line of sight in the normal plane through the line of sight.



As

Relative Angular Movement in Elevation

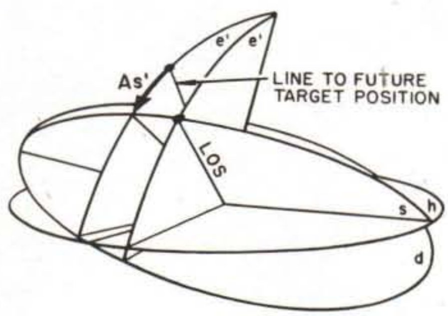
Angle between the line to the future target position, and the slant plane through the line of sight and through the director elevation axis in the horizontal, measured from the line to the future target position in the vertical plane through the line to the future target position.



As'

Relative Angular Movement in Elevation

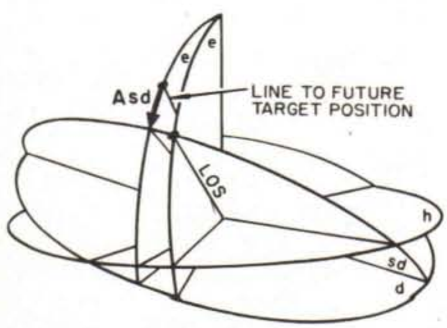
Angle between the line to the future target position, and the slant plane through the line of sight and through the director elevation axis in the horizontal, measured from the line to the future target position in the normal plane through the line to the future target position.



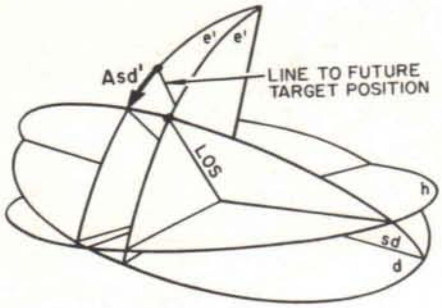
Asd

Relative Angular Movement in Elevation

Angle between the line to the future target position, and the slant plane through the line of sight and through the director elevation axis in the deck, measured from the line to the future target position in the vertical plane through the line to the future target position.



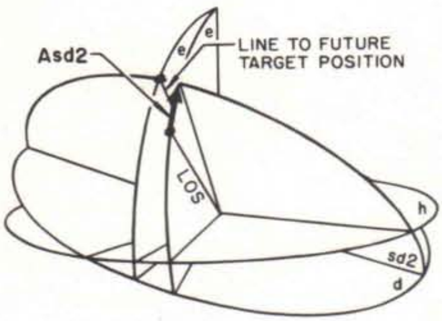
Asd′



Relative Angular Movement in Elevation

Angle between the line to the future target position, and the slant plane through the line of sight and through the director elevation axis in the deck, measured from the line to the future target position in the normal plane through the line to the future target position.

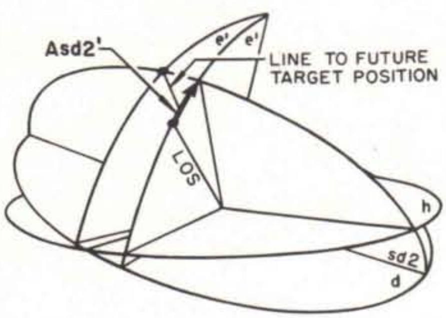
Asd2



Relative Angular Movement in Elevation

Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the deck, measured from the line of sight in the vertical plane through the line of sight.

Asd2′



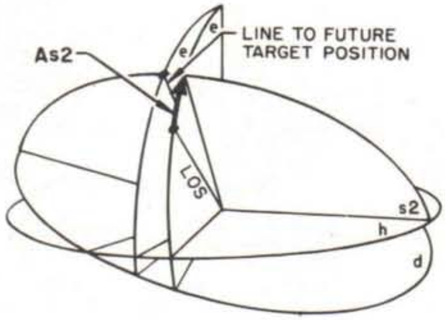
Relative Angular Movement in Elevation

Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the deck, measured from the line of sight in the normal plane through the line of sight.

As2

Relative Angular Movement in Elevation

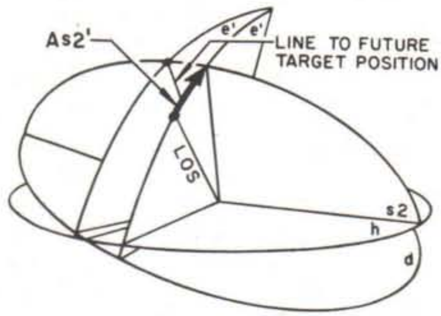
Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the horizontal, measured from the line of sight in the vertical plane through the line of sight.



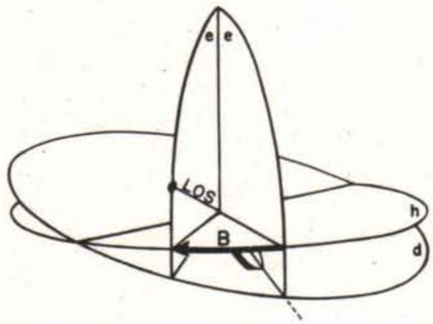
As2′

Relative Angular Movement in Elevation

Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the horizontal, measured from the line of sight in the normal plane through the line of sight.



B



Relative Target Bearing

Angle between the vertical plane through own ship centerline, and the vertical plane through the line of sight, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

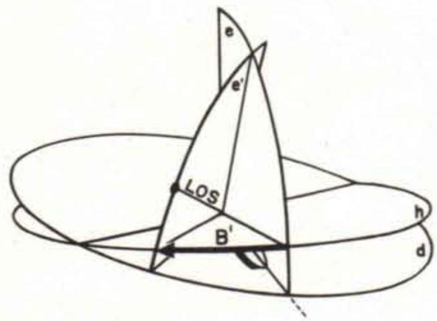
Note: 1. Previously used for true target bearing. See ***By***
2. Previously called *Br*

dB

True Angular Bearing Rate

See ***DBy***

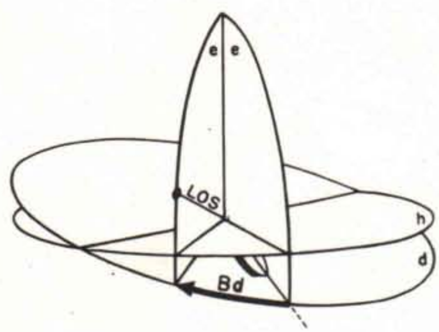
B′



Relative Target Bearing

Angle between the vertical plane through own ship centerline, and the normal plane through the line of sight, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

Bd



Director Train (Stabilized Sight)

Angle between the vertical plane through own ship centerline, and the vertical plane through the line of sight, measured in the deck plane. Positive angles measured clockwise from own ship centerline.

Note: 1. Previously called *B′r*

j(Bd)

Deck Tilt Correction

The addition to director train ***Bd*** to obtain relative target bearing ***B***. $B = Bd + j(Bd)$

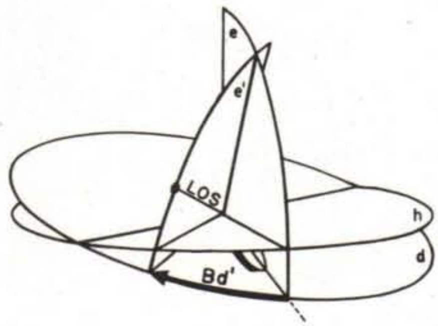
Note: 1. Previously called *jB′r*

Bd′

Director Train (Unstabilized Sight)

Angle between the vertical plane through own ship centerline, and the normal plane through the line of sight, measured in the deck plane. Positive angles measured clockwise from own ship centerline.

Note: 1. Previously called *B′r′*



j(Bd′)

Deck Tilt Correction

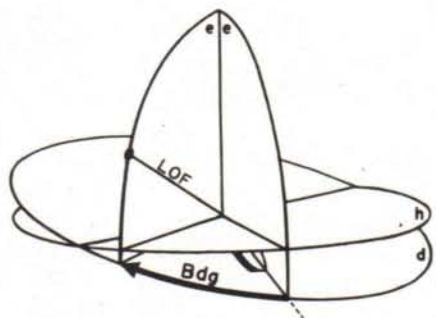
The addition to director train Bd′ to obtain relative target bearing ***B***. ***B*** = ***Bd′*** + ***j***(***Bd′***)

Note: 1. Previously called *jB′r′*

Bdg

Relative Gun Train

Angle between the vertical plane through own ship centerline, and the vertical plane through the line of fire, measured in the deck plane. Positive angles measured clockwise from own ship centerline.

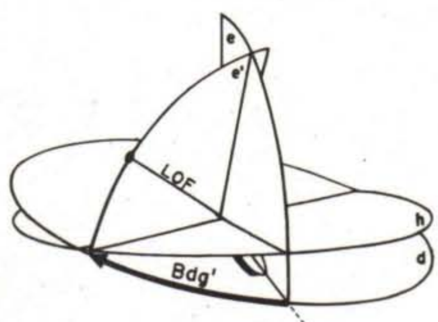


Bdg′

Gun Train Order

Angle between the vertical plane through own ship centerline, and the normal plane through the line of fire, measured in the deck plane. Positive angles measured clockwise from own ship centerline.

Note: 1. Previously called *B′gr*



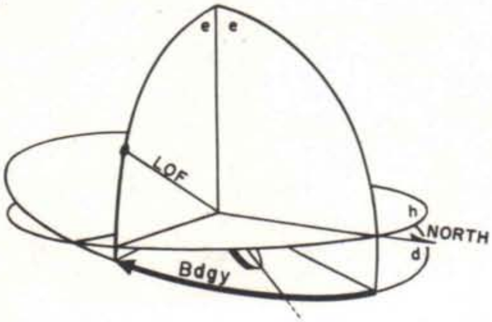
pl(Bdg′)

Unit Parallax

The correction applied to gun train order as computed for the reference point to obtain gun train order for a gun displaced 100 yards from the reference point.

Note: 1. Previously called *Ph*

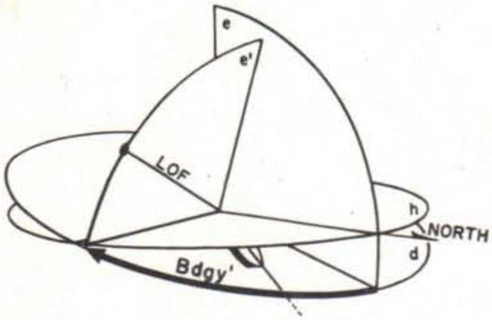
Bdgy



True Gun Train

Angle between the North-South vertical plane, and the vertical plane through the line of fire, measured in the deck plane. Positive angles measured clockwise from North.

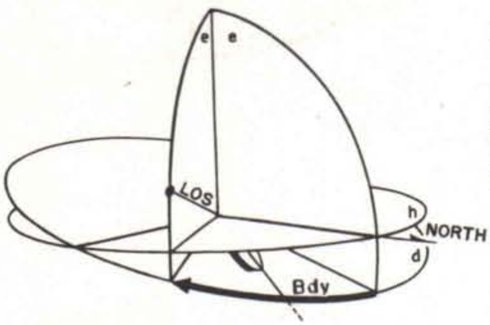
Bdgy'



True Gun Train Order

Angle between the North-South vertical plane, and the normal plane through the line of fire, measured in the deck plane. Positive angles measured clockwise from North.

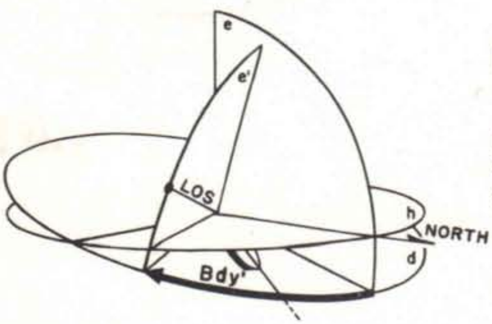
Bdy



True Director Train (Stabilized Sight)

Angle between the North-South vertical plane, and the vertical plane through the line of sight, measured in the deck plane. Positive angles measured clockwise from North.

Bdy'



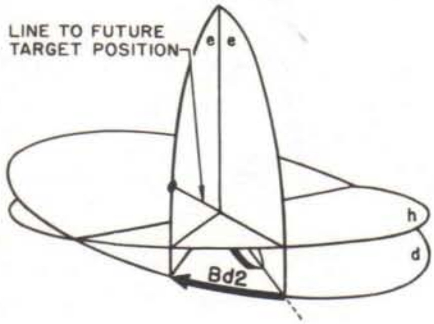
True Director Train (Unstabilized Sight)

Angle between the North-South vertical plane, and the normal plane through the line of sight, measured in the deck plane. Positive angles measured clockwise from North.

Bd2

Relative Train to Future Target Position

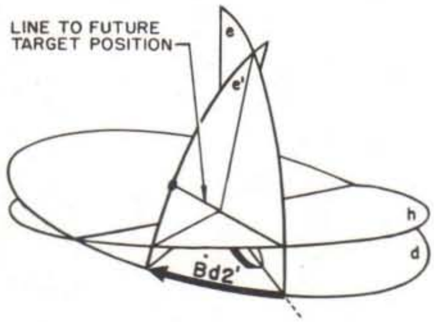
Angle between the vertical plane through own ship centerline, and the vertical plane through the line to the future target position, measured in the deck plane. Positive angles measured clockwise from own ship centerline.



Bd2′

Relative Train to Future Target Position

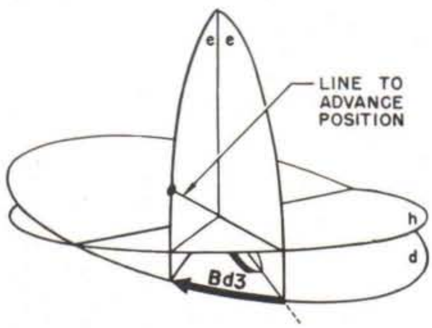
Angle between the vertical plane through own ship centerline, and the normal plane through the line to the future target position, measured in the deck plane. Positive angles measured clockwise from own ship centerline.



Bd3

Relative Train to Advance Position

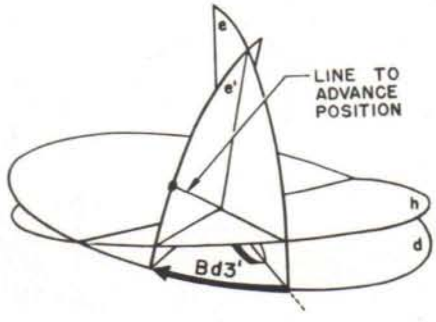
Angle between the vertical plane through own ship centerline, and the vertical plane through the line to the advance position, measured in the deck plane. Positive angles measured clockwise from own ship centerline.



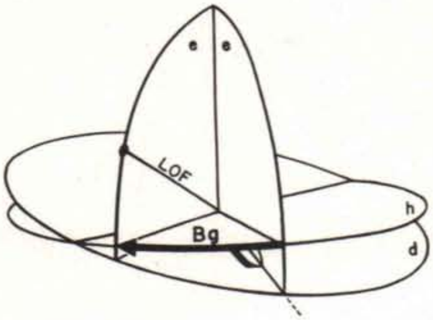
Bd3′

Relative Train to Advance Position

Angle between the vertical plane through own ship centerline, and the normal plane through the line to the advance position, measured in the deck plane. Positive angles measured clockwise from own ship centerline.



Bg

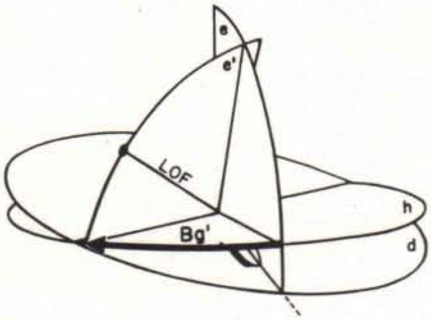


Relative Gun Bearing

Angle between the vertical plane through own ship centerline, and the vertical plane through the line of fire, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

Note: 1. Previously called *Bgr*
2. Previously used for true gun bearing See ***Bgy***

Bg′



Relative Gun Bearing

Angle between the vertical plane through own ship centerline, and the normal plane through the line of fire, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

Bgr

Relative Gun Bearing

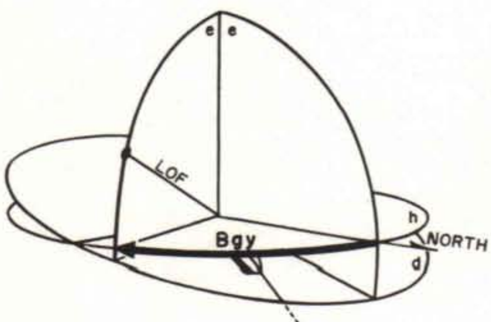
See ***Bg***

B′gr

Gun Train Order

See ***Bdg′***

Bgy



True Gun Bearing

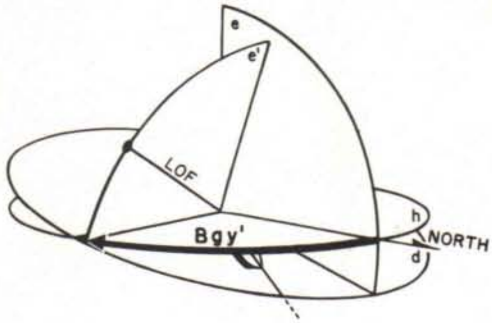
Angle between the North-South vertical plane, and the vertical plane through the line of fire, measured in the horizontal plane. Positive angles measured clockwise from North.

Note: 1. Previously called *Bg*

Bgy'

True Gun Bearing

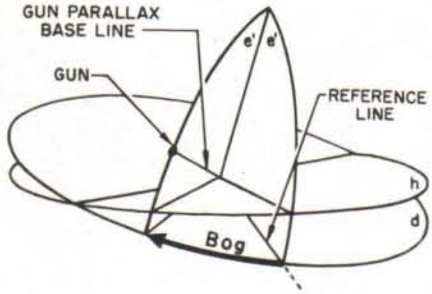
Angle between the North-South vertical plane, and the normal plane through the line of fire, measured in the horizontal plane. Positive angles measured clockwise from North.



Bog

Gun Parallax Angle

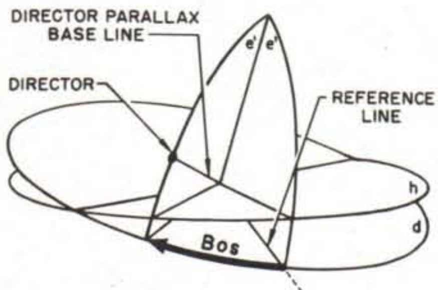
Angle between normal plane through reference line, and normal plane through gun parallax base line, measured in deck plane clockwise from reference line.



Bos

Director Parallax Angle

Angle between normal plane through reference line, and normal plane through director parallax base line, measured in deck plane clockwise from reference line.

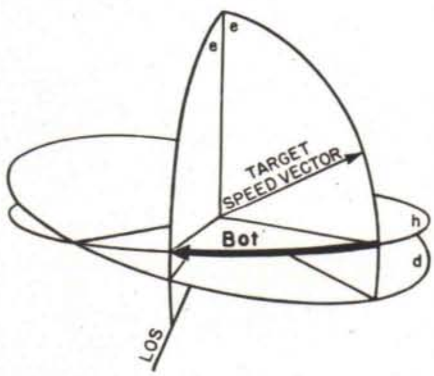


Bot

Target Angle

Angle between vertical plane through the relative target speed vector, and the vertical plane through the line of sight, measured in the horizontal plane clockwise from the target speed vector.

Note: 1. Previously called *A*



dBr

Relative Angular Bearing Rate

See ***DB***

Br

Relative Target Bearing

See ***B***

B'r

Director Train (Stabilized Sight)

See ***Bd***

jB'r

Deck Tilt Correction

See ***j*(*Bd*)**

B'r'

Director Train (Unstabilized Sight)

See ***Bd'***

jB'r'

Deck Tilt Correction

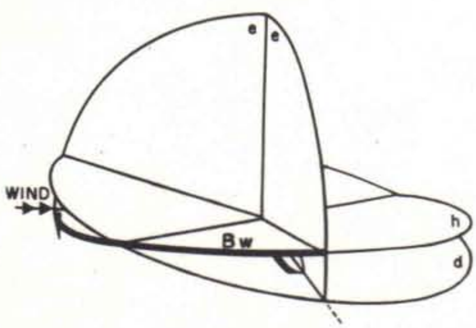
See ***j*(*Bd'*)**

dBs

Angular Bearing Rate in Slant Plane

See ***DBs***

Bw



Relative Direction True Wind

Angle between the vertical plane through own ship centerline, and the vertical plane through the direction from which the true wind is blowing, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

Note: 1. Previously called *Bwr*
2. Previously used for True Direction True Wind. See ***Bwy***
3. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwa***

Bwa

Relative Direction Apparent Wind

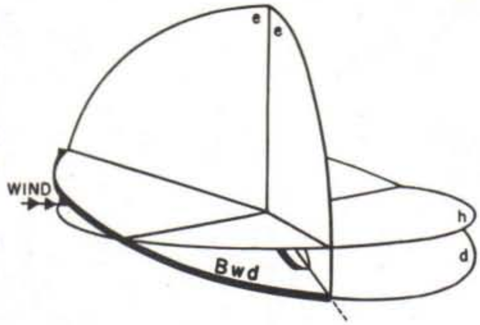
See Note 3 under ***Bw***

Note: 1. Previously called ***Bwra***
2. Previously used for True Direction Apparent Wind. See ***Bwya***

Bwd

Angle between the vertical plane through own ship centerline, and the vertical plane through the director from which the true wind is blowing, measured in the deck plane. Positive angles measured clockwise from own ship centerline.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added and symbol becomes ***Bwda***



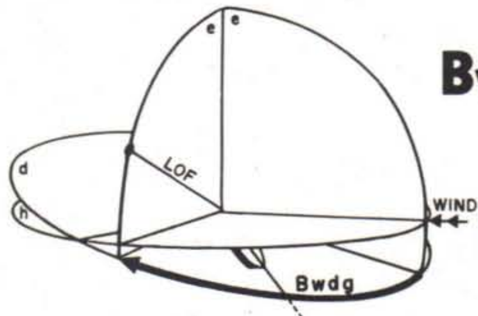
Bwda

See Note 1 under ***Bwd***

Bwdg

Angle between the vertical plane through the director from which the true wind is blowing and the vertical plane through the line of fire, measured in the deck plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

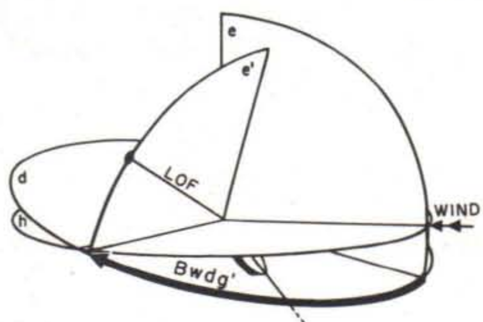
Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwdga***
2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwdgo***



Bwdg′

Angle between the vertical plane through the director from which the true wind is blowing, and the normal plane through the line of fire, measured in the deck plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwdga′***
2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwdgo′***



Bwdga

See Note 1 under ***Bwdg***

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Bwdga′

See Note 1 under ***Bwdg′***

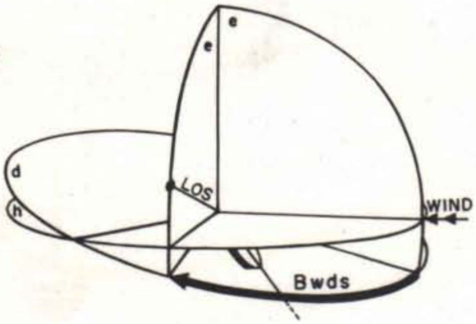
Bwdgo

See Note 2 under ***Bwdg***

Bwdgo′

See Note 2 under ***Bwdg′***

Bwds

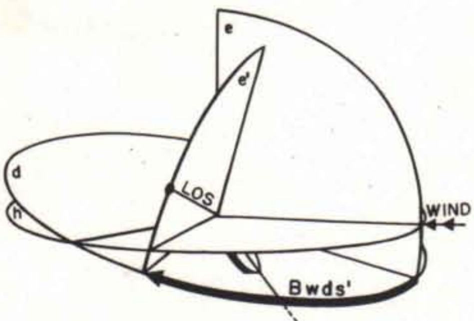


Angle between the vertical plane through the direction from which the true wind is blowing, and the vertical plane through the line of sight, measured in the deck plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwdsa***

2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwdso***

Bwds′



Angle between the vertical plane through the direction from which the true wind is blowing, and the normal plane through the line of sight, measured in the deck plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwdsa′***

2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwdso′***

Bwdsa

See Note 1 under ***Bwds***

Bwdsa′

See Note 1 under ***Bwds′***

Bwdso

See Note 2 under ***Bwds***

Bwdso′

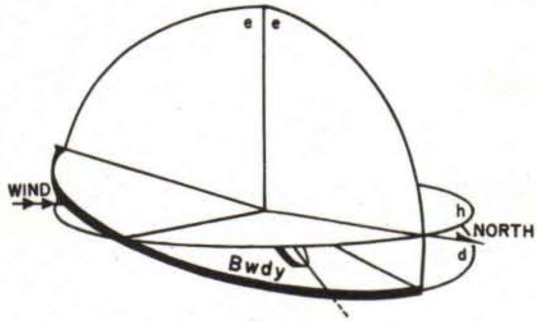
See Note 2 under ***Bwds′***

Bwdy

Angle between the North-South vertical plane, and the vertical plane through the direction from which the true wind is blowing, measured in the deck plane. Positive angles measured clockwise from North.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwdya***

2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwdyo***



Bwdya

See Note 1 under ***Bwdy***

Bwdyo

See Note 2 under ***Bwdy***

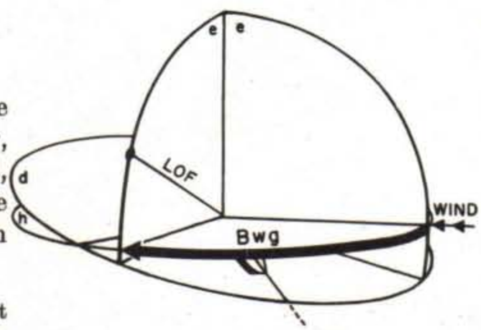
Bwg

Predicted True Wind Angle

Angle between the vertical plane through the direction from which the true wind is blowing, and the vertical plane through the line of fire, measured in the horizontal plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

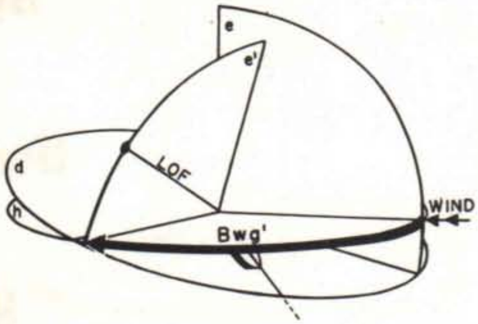
Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwga***

2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwgo***



891927 O—5

Bwg'



Angle between the vertical plane through the direction from which the true wind is blowing, and the normal plane through the line of fire, measured in the horizontal plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwga'***

2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwgo'***

Bwga

Predicted Apparent Wind Angle

See Note 1 under ***Bwg***

Bwga'

See Note 1 under ***Bwg'***

Bwgo

Predicted Own Ship Wind Angle

See Note 2 under ***Bwg***

Bwgo'

See Note 2 under ***Bwg'***

Bwr

Relative Direction True Wind

See ***Bw***

Bwra

Relative Direction Apparent Wind

See ***Bwa***

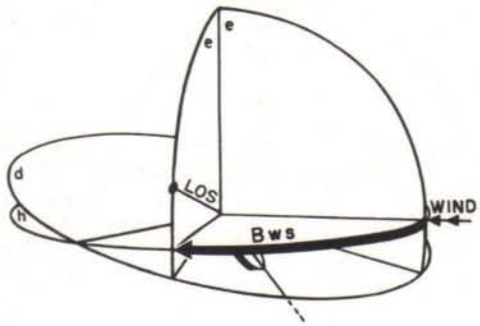
Bws

True Wind Angle

Angle between the vertical plane through the direction from which the true wind is blowing, and the vertical plane through the line of sight, measured in the horizontal plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwsa***

2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwso***

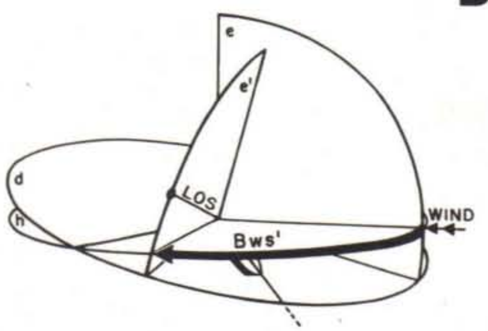


Bws'

Angle between the vertical plane through the direction from which the true wind is blowing, and the normal plane through the line of sight, measured in the horizontal plane. Positive angles measured clockwise from the direction from which the true wind is blowing.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwsa'***

2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwso'***



Apparent Wind Angle

Bwsa

See Note 1 under ***Bws***

Bwsa'

See Note 1 under ***Bws'***

Own Ship Wind Angle

Bwso

See Note 2 under ***Bws***

Bwso'

See Note 2 under ***Bws'***

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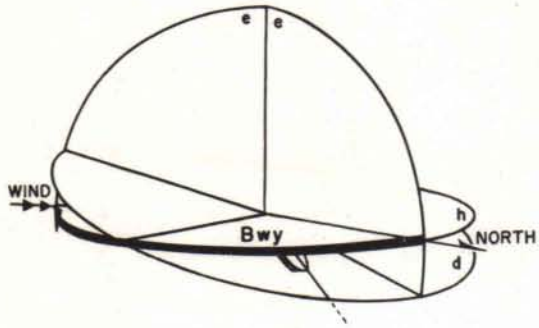
Bwy



True Direction True Wind

Angle between the North-South vertical plane, and the vertical plane through the direction from which the true wind is blowing, measured in the horizontal plane. Positive angles measured clockwise from North.

Note: 1. Previously called ***Bw***
2. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Bwya***
3. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Bwyo***

Bwya

True Direction Apparent Wind

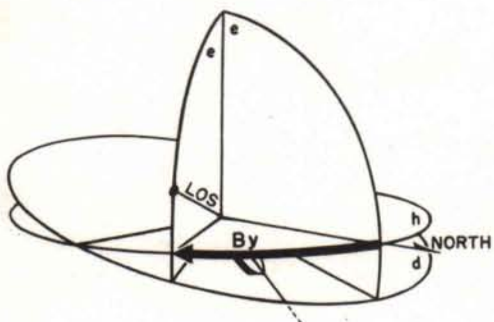
See Note 2 under ***Bwy***

Bwyo

True Direction Own Ship Wind

See Note 3 under ***Bwy***

By

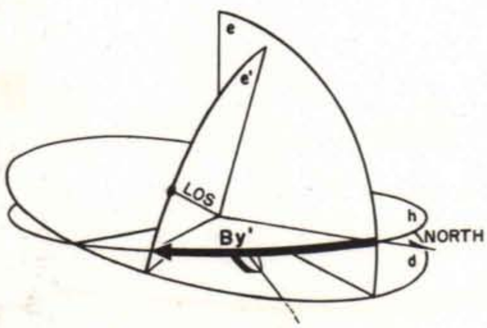


True Target Bearing

Angle between the North-South vertical plane, and the vertical plane through the line of sight, measured in the horizontal plane. Positive angles measured clockwise from North.

Note: 1. Previously called *B*

By'



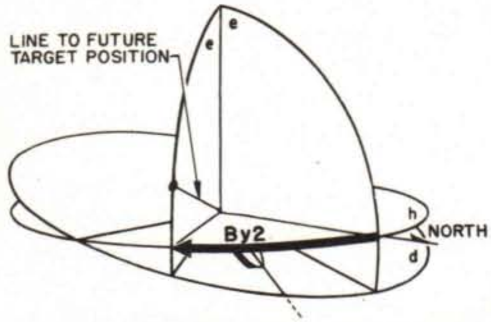
True Target Bearing

Angle between the North-South vertical plane, and the normal plane through the line of sight, measured in the horizontal plane. Positive angles measured clockwise from North.

By2

True Bearing of Future Target Position

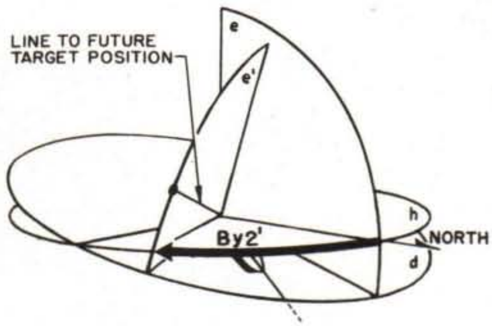
Angle between the North-South vertical plane, and the vertical plane through the line to the future target position, measured in the horizontal plane. Positive angles measured clockwise from North.



By2′

True Bearing of Future Target Position

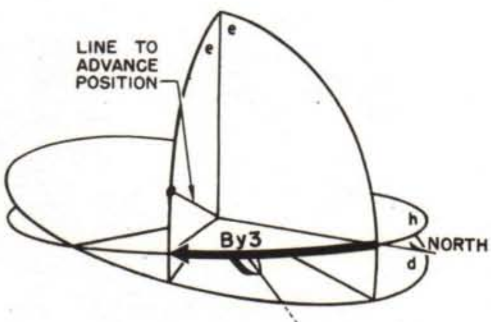
Angle between the North-South vertical plane, and the normal plane through the line to the future target position, measured in the horizontal plane. Positive angles measured clockwise from North.



By3

True Bearing of Advance Position

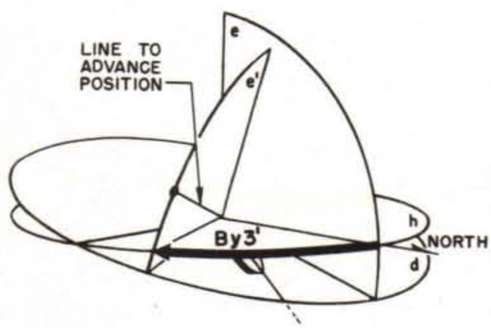
Angle between the North-South vertical plane, and the vertical plane through the line to the advance position, measured in the horizontal plane. Positive angles measured clockwise from North.



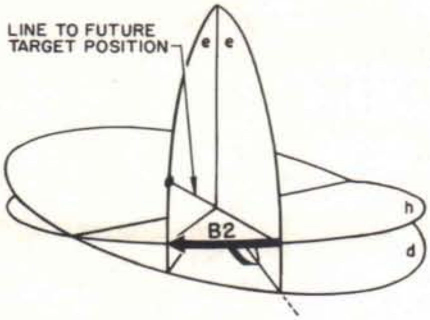
By3′

True Bearing of Advance Position

Angle between the North-South vertical plane, and the normal plane through the line to the advance position, measured in the horizontal plane. Positive angles measured clockwise from North.



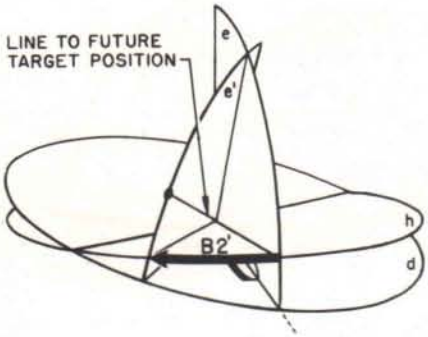
B2



Relative Bearing of Future Target Position

Angle between the vertical plane through own ship centerline, and the vertical plane through the line to the future target position, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

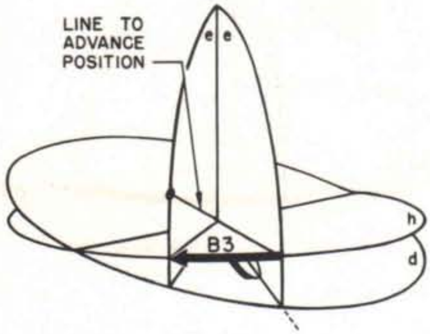
B2′



Relative Bearing of Future Target Position

Angle between the vertical plane through own ship centerline, and the normal plane through the line to the future target position, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

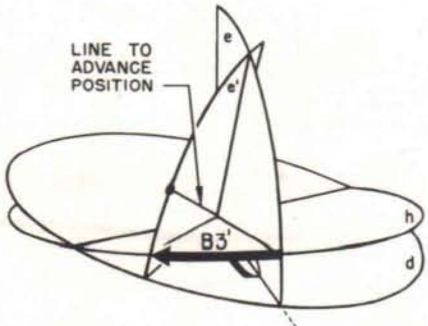
B3



Relative Bearing of Advance Position

Angle between the vertical plane through own ship centerline, and the vertical plane through the line to the advance position, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

B3′



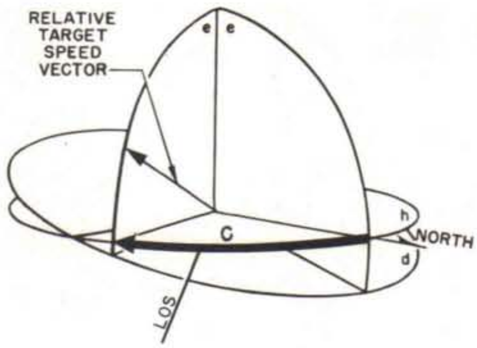
Relative Bearing of Advance Position

Angle between the vertical plane through own ship centerline, and the normal plane through the line to the advance position, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.

C

Relative Target Course

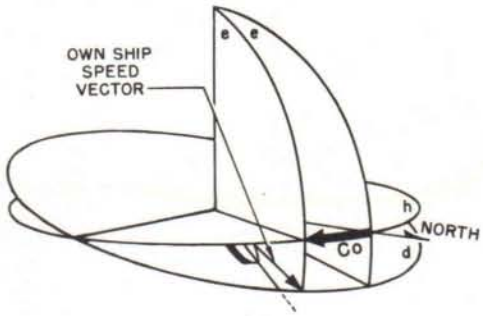
Angle between the North-South vertical plane, and the vertical plane through the target speed vector relative to own ship (referred to the frame used by the fire control system), measured in the horizontal plane. Positive angles measured clockwise from North



Co

Own Ship Course

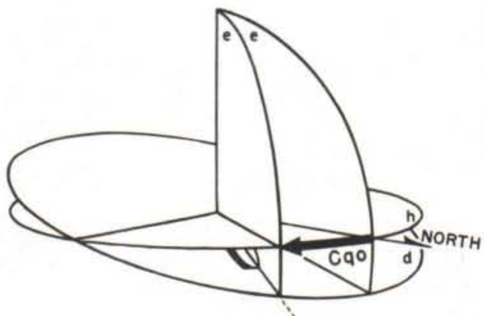
Angle between the North-South vertical plane, and the vertical plane through own ship speed vector (referred to the plane used by the fire control system), measured in the horizontal plane. Positive angles measured clockwise from North.



Cqo

Own Ship Heading

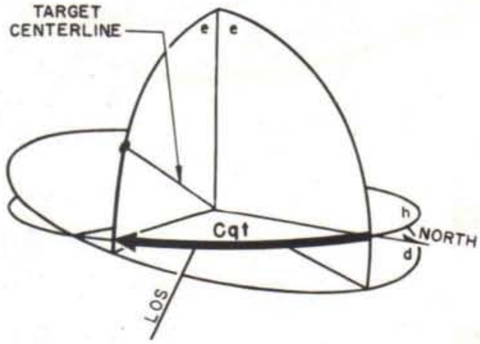
Angle between the North-South vertical plane, and the vertical plane through own ship centerline, measured in the horizontal plane. Positive angles measured clockwise from North.



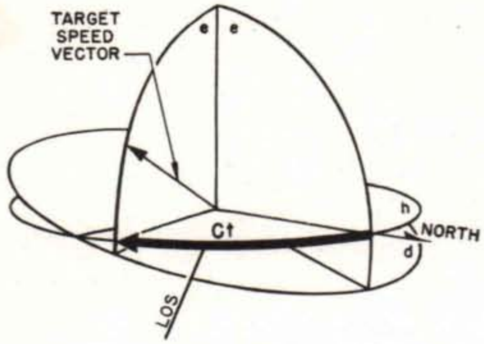
Cqt

Target Heading

Angle between the North-South vertical plane, and the vertical plane through the target centerline, measured in the horizontal plane. Positive angles measured clockwise from North.



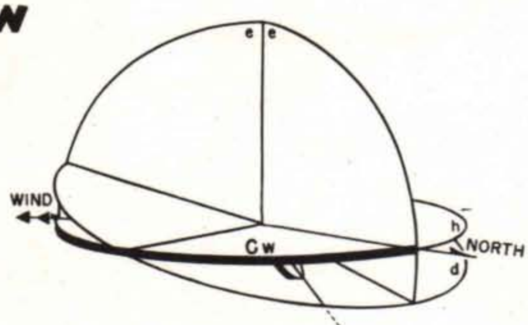
Ct



Target Course

Angle between the North-South vertical plane, and the vertical plane through the target speed vector (referred to the frame used by the fire control system), measured in the horizontal plane. Positive angle measured clockwise from North.

Cw



True Course True Wind

Angle between the North-South vertical plane, and the vertical plane through the direction toward which the true wind is blowing, measured in the horizontal plane. Positive angles measured clockwise from North.

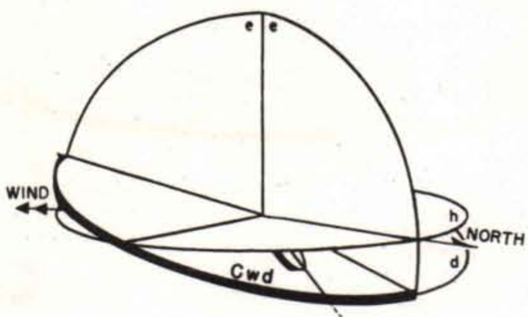
Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Cwa***
2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Cwo***

Cwa

True Course Apparent Wind

See Note 1 under ***Cw***

Cwd



Angle between the North-South vertical plane, and the vertical plane through the director toward which the true wind is blowing, measured in the deck plane. Positive angles measured clockwise from North.

Note: 1. To express the same angle of the apparent wind, modifier ***a*** is added, and symbol becomes ***Cwda***
2. To express the same angle of own ship wind, modifier ***o*** is added, and symbol becomes ***Cwdo***

Cwda

See Note 1 under ***Cwd***

Cwdo

See Note 2 under ***Cwd***

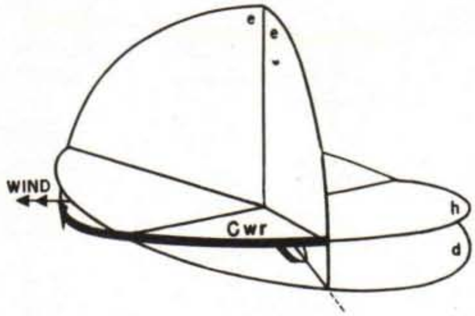
Cwo

See Note 2 under *Cw*

Cwr

Relative Course True Wind

Angle between the vertical plane through own ship centerline, and the vertical plane through the direction toward which the true wind is blowing, measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.



Note: 1. To express the same angle of the apparent wind, modifier *a* is added, and symbol becomes *Cwra*

Cwra

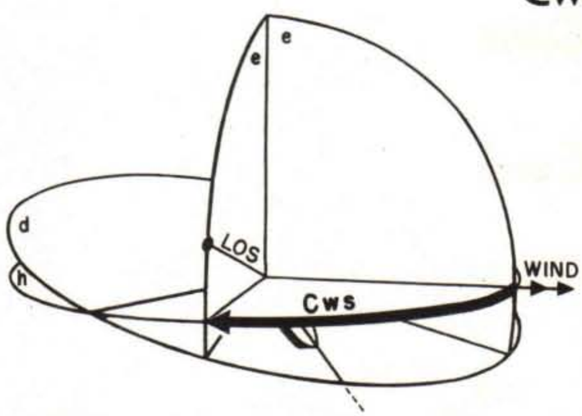
Relative Course Apparent Wind

See Note 1 under *Cwr*

Cws

Wind Angle

Angle between the vertical plane through the direction toward which the true wind is blowing, and the vertical plane through the line of sight measured in the horizontal plane. Positive angles measured clockwise from the direction toward which the true wind is blowing.

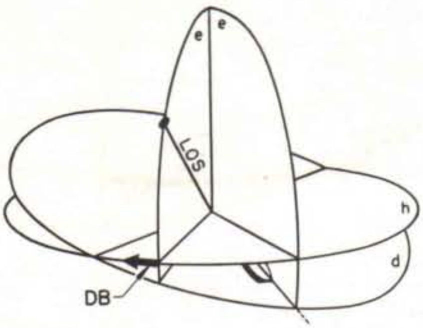


D

Differentiating operator (d/dt) where the derivative is taken with respect to time at the instant of firing.

Note: 1. Previously used for sight deflection. See *Ls''*

DB

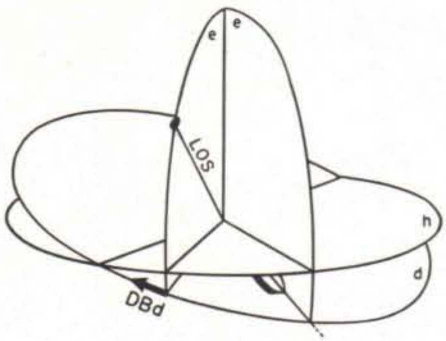


Relative Angular Bearing Rate

The angular rate of the line of sight in the horizontal plane measured with respect to the intersection of the horizontal plane and the vertical plane through own ship centerline.

Note: 1. This is the time rate of change of relative target bearing
2. Previously called *dBr*

DBd

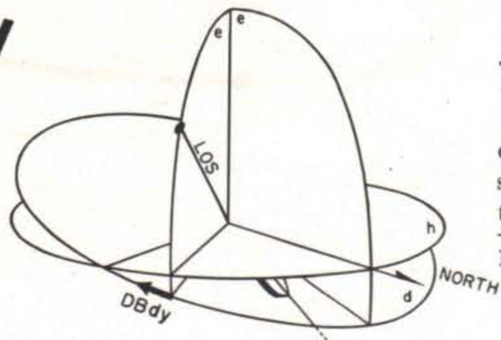


Relative Angular Train Rate

The angular rate of the line of sight in the deck plane measured with respect to own ship centerline.

Note: 1. This is the time rate of change of director train

DBdy



True Angular Train Rate

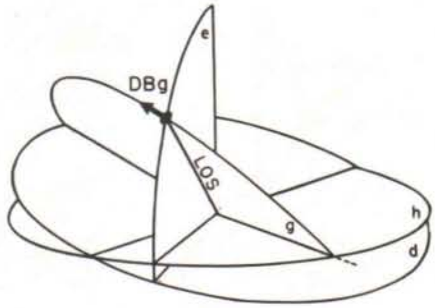
The angular rate of the line of sight in the deck plane measured with respect to the intersection of the North-South vertical plane and the deck plane.

Note: 1. This is the time rate of change of true director train

DBg

Angular Bearing Rate in Slant Plane

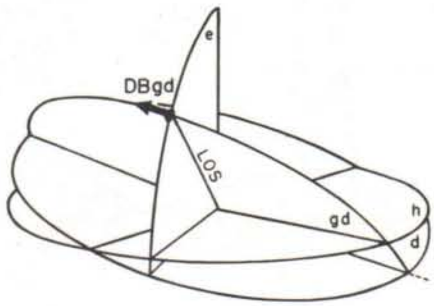
The angular rate of the line of sight in the slant plane through the line of sight and through the gun elevation axis in the horizontal plane, measured with respect to the initial position of the line of sight at the instant of firing. The initial position of the line of sight is fixed in the reference frame used by the fire control system to measure the angular rate.



DBgd

Angular Bearing Rate in Slant Plane

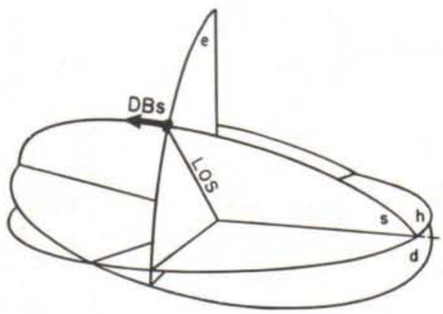
The angular rate of the line of sight in the slant plane through the line of sight and through the gun elevation axis in the deck plane, measured with respect to the initial position of the line of sight at the instant of firing. The initial position of the line of sight is fixed in the reference frame used by the fire control system to measure the angular rate.



DBs

Angular Bearing Rate in Slant Plane

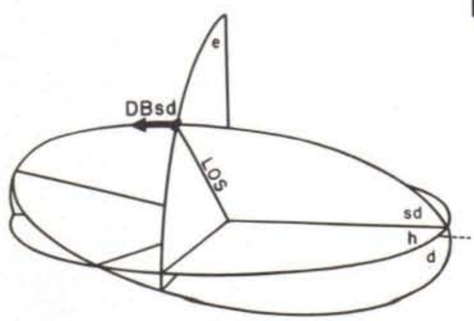
The angular rate of the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane, measured with respect to the initial position of the line of sight at the instant of firing. The initial position of the line of sight is fixed in the reference frame used by the fire control system to measure the angular rate.



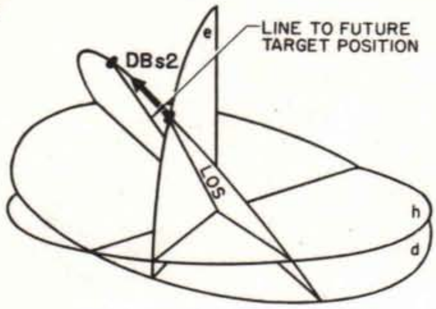
DBsd

Angular Bearing Rate in Slant Plane

The angular rate of the line of sight in the slant plane through the line of sight and through the director elevation axis in the deck plane, measured with respect to the initial position of the line of sight at the instant of firing. The initial position of the line of sight is fixed in the reference frame used by the fire control system to measure the angular rate.



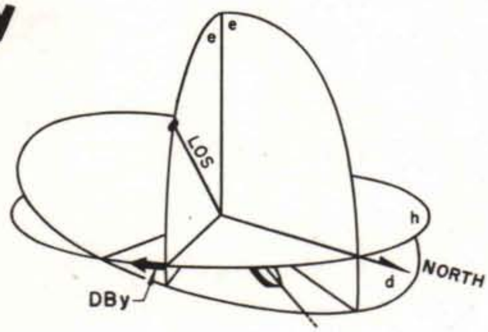
DBs2



Angular Rate in Prediction Plane

The angular rate of the line of sight in the slant plane through the line of sight and through the relative target speed vector, measured with respect to the initial position of the line of sight at the instant of firing. The initial position of the line of sight is fixed in the reference frame used by the fire control system to measure the angular rate.

DBy

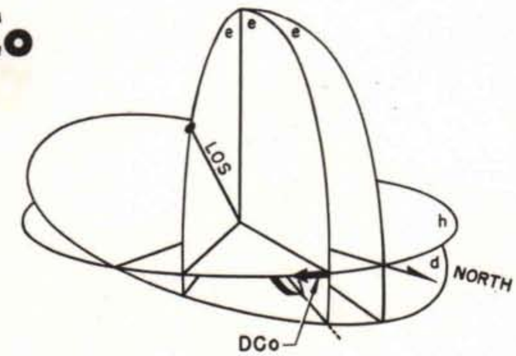


True Angular Bearing Rate

The angular rate of the line of sight in the horizontal plane, measured with respect to North.

Note: 1. This is the time rate of change of true target bearing
2. Previously called *dB*
3. Equal to time rate of change of relative target bearing when own ship course is constant

DCo



Own Ship Course Rate

The angular rate of own ship speed vector in the horizontal plane, measured with respect to North.

Note: 1. This is the time rate of change of own ship course

Dd

Deck Deflection

See ***Ld***

Dd′

Deck Deflection

See ***Ld′***

D′d

Deck Deflection

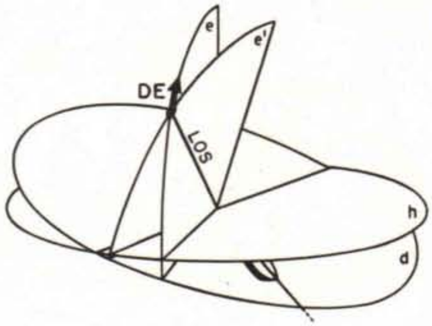
See ***′Ld′***

DE

Angular Elevation Rate

The angular rate of the line of sight in the vertical plane though the line of sight, measured with respect to the intersection of the vertical plane through the line of sight and the horizontal plane.

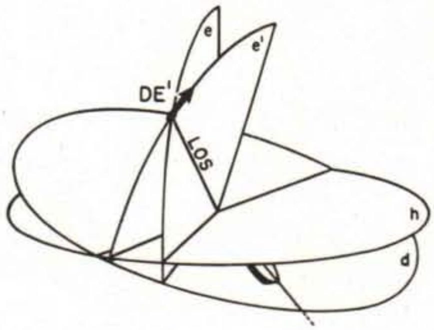
Note: 1. Previously called *dE*.
2. This is the time rate of change of target elevation



DE′

Angular Elevation Rate

The angular rate of the line of sight in the normal plane through the line of sight, measured with respect to the intersection of the normal plane through the line of sight and the horizontal plane.

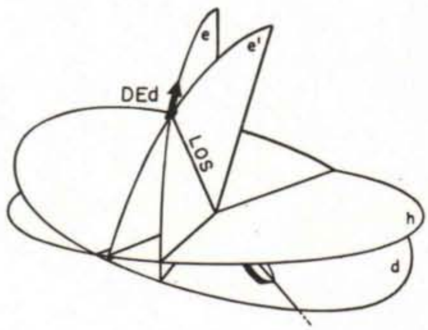


DEd

Angular Director Elevation Rate

The angular rate of the line of sight in the vertical plane through the line of sight, measured with respect to the intersection of the vertical plane through the line of sight and the deck plane.

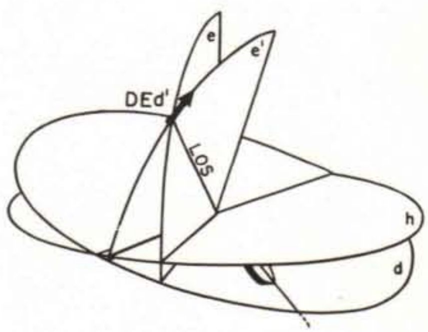
Note: 1. This is the time rate of change of director elevation



DEd′

Angular Director Elevation Rate

The angular rate of the line of sight in the normal plane through the line of sight, measured with respect to the intersection of the normal plane through the line of sight and the deck plane.



Df — **Drift in Horizontal**

Dfs — **Drift in Traverse**

Dh — **Horizontal Deflection**

See ***Lh***

DL — **Rate of Change of Lead Angle**

The rate at which the total lead angle between the line of sight and the line of fire is changing.

Note: 1. To express the rate of change of any traverse or elevation lead angle, the symbol for the angle is enclosed in parentheses and preceded by ***D***

DM2 — **Average Target Speed**

The average relative speed of the target to the future position, referred to the frame used by the fire control system.

Ds — **Sight Deflection**

See ***Ls***

D's — **Sight Deflection**

See ***'Lsdg***

Dt

The part of sight deflection accounting for relative motion between own ship and target.

Note: 1. Now symbolized by enclosing the applicable sight angle in parentheses and preceding by ***m***. For example, ***m*(*Ls*)**

Dw

The part of sight angle accounting for the effect of wind on the projectile during the time of flight.

Note: 1. Now symbolized by enclosing the applicable sight angle in parentheses and preceding by ***w***. For example, ***w*(*Ls*)**

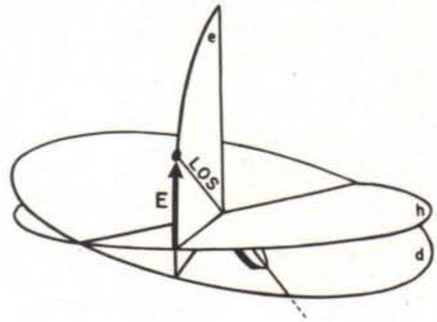
Dz — **Trunnion Tilt Correction**

See ***Lz***

E

Target Elevation

Angle between the horizontal plane and the line of sight, measured in the vertical plane through the line of sight. Positive angles measured upward from the horizontal plane.



dE

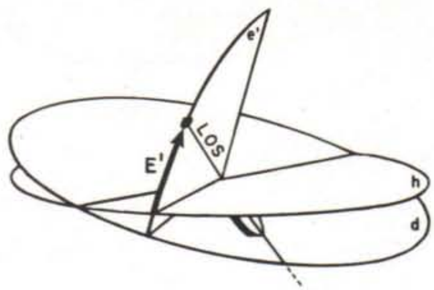
Angular Elevation Rate

See ***DE***

E′

Target Elevation

Angle between the horizontal plane and the line of sight, measured in the normal plane through the line of sight. Positive angles measured upward from the horizontal plane.



Eb

Director Elevation

See ***Ed***

E′b

Director Elevation

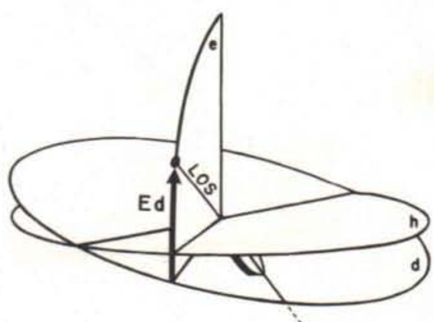
See ***Ed′***

Ed

Director Elevation

Angle between the deck plane and the line of sight, measured in the vertical plane through the line of sight. Positive angles measured upward from the deck plane.

Note: 1. Previously called ***Eb***



Gene Slover's US Navy Pages

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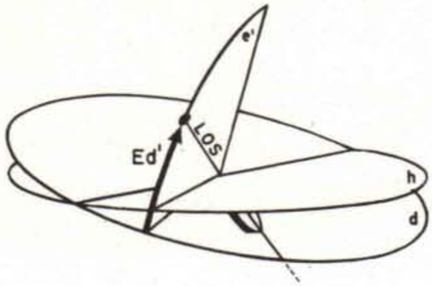
Ed′

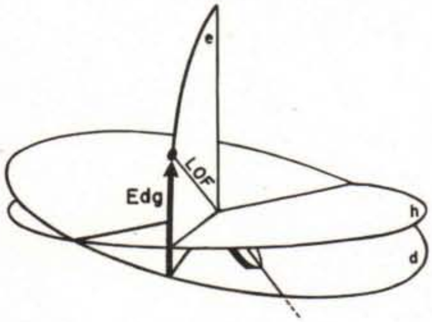


Director Elevation

Angle between the deck plane and the line of sight, measured in the normal plane through the line of sight. Positive angles measured upward from the deck plane.

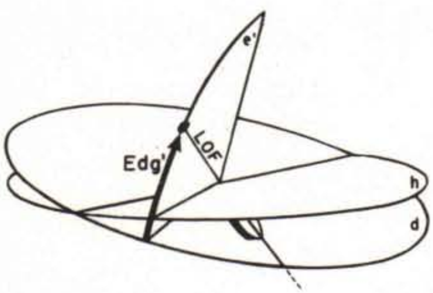
Note: 1. Previously called ***E′b***

Edg



Angle between the deck plane and the line of fire, measured in the vertical plane through the line of fire. Positive angles measured upward from the deck plane.

Edg′

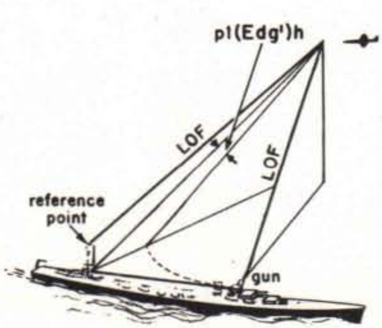


Gun Elevation Order

Angle between the deck plane and the line of fire, measured in the normal plane through the line of fire. Positive angles measured upward from the deck plane.

Note: 1. Previously called *E′g*

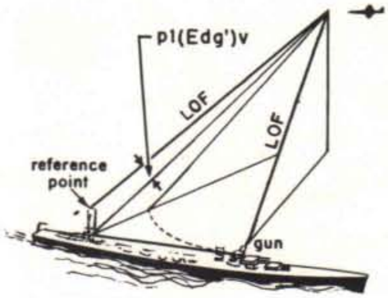
pl (Edg′)h



The correction to gun elevation order computed for the reference point to account for a 100 yard displacement in the deck between the gun and reference point.

Note: 1. Previously called *Pv*

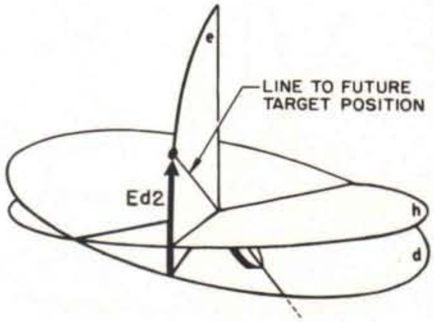
pl (Edg′)v



The correction to gun elevation order computed for the reference point to account for a ten yard vertical displacement between the gun and reference point.

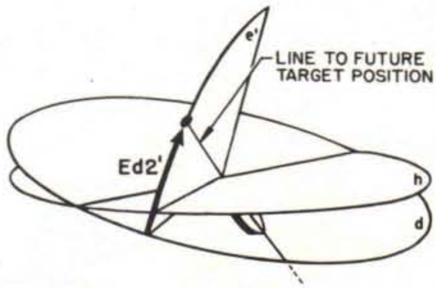
Note: 1. Previously called *Pe*

Ed2



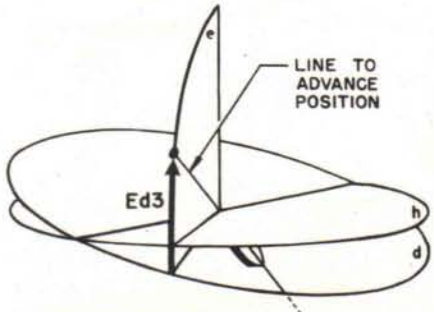
The angle between the deck plane and the line to the future target position, measured in the vertical plane through the line to the future target position. Positive angles measured upward from the deck plane.

Ed2′



The angle between the deck plane and the line to the future target position, measured in the normal plane through the line to the future target position. Positive angles measured upward from the deck plane.

Ed3



Angle between the deck plane and the line to the advance position, measured in the vertical plane through the line to the advance position. Positive angles measured upward from the deck plane.

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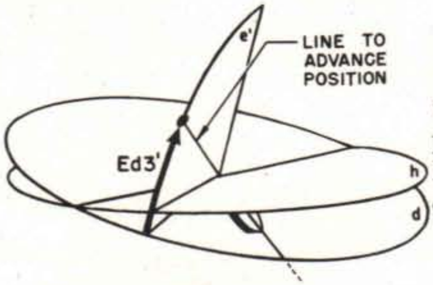
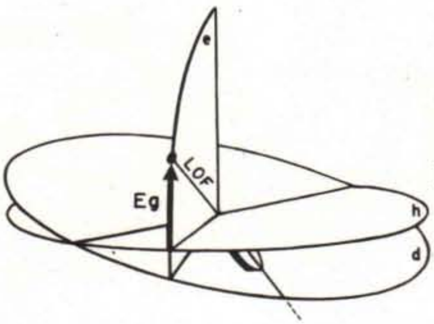
Ed3′



Angle between the deck plane and the line to the advance position, measured in the normal plane through the line to the advance position. Positive angles measured upward from the deck plane.

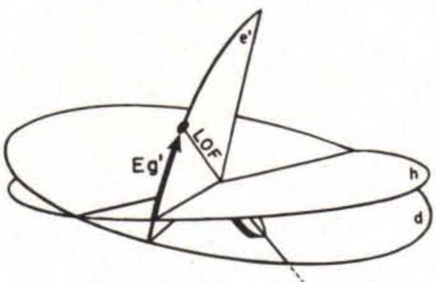
Eg



Gun Elevation

Angle between the horizontal plane and the line of fire, measured in the vertical plane through the line of fire. Positive angles measured upward from the horizontal plane.

Eg′



Gun Elevation

Angle between the horizontal plane and the line of fire, measured in the normal plane through the line of fire. Positive angles measured upward from the horizontal plane.

E′g

Gun Elevation Order

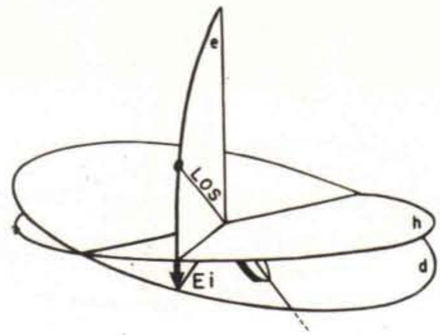
See ***Edg′***

Ei

Level Angle

Angle between the horizontal plane and the deck plane, measured in the vertical plane through the line of sight. Positive angles measured downward from the horizontal plane on the target side of own ship.

Note: 1. Previously called *L*

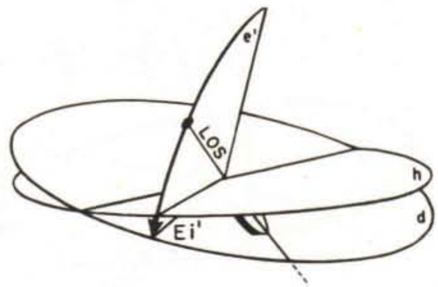


Ei′

Level Angle

Angle between the horizontal plane and the deck plane, measured in the normal plane through the line of sight. Positive angles measured downward from the horizontal plane on the target side of own ship.

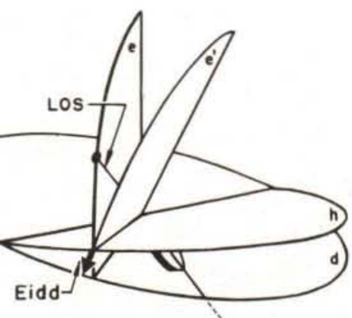
Note: 1. Previously called *L′*



Eidd

Level Angle

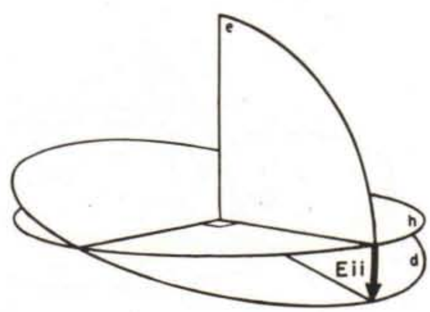
Angle between the horizontal plane and the deck plane, measured in the normal plane through the intersection of the horizontal plane and the vertical plane through the line of sight. Positive angles measured downward from the horizontal plane on the target side of own ship.



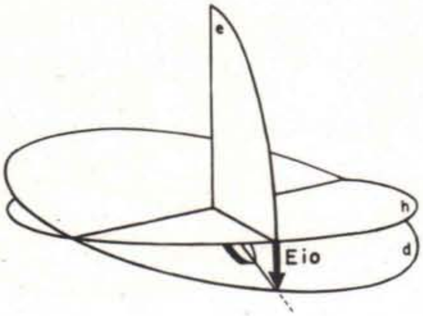
Eii

Level Angle

Angle between the horizontal and deck planes, measured in the vertical plane perpendicular to the intersection of the deck plane and the horizontal plane. Positive angles measured downward from the horizontal plane. This is the dihedral angle between the horizontal plane and the deck plane.



Eio

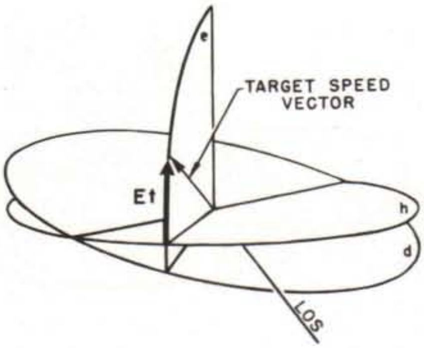


Pitch

Angle between the horizontal plane and the deck plane, measured in the vertical plane through own ship centerline. Positive angles measured downward from the horizontal plane.

Note: 1. Previously called *N*

Et

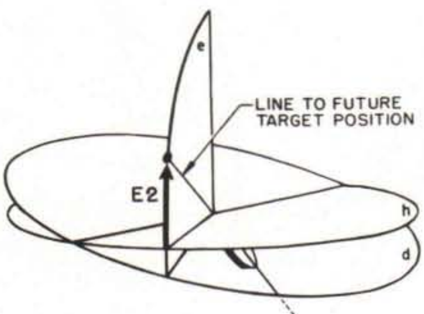


Angle of Climb or Dive

Angle between the horizontal plane, and the relative target speed vector referred to the frame used by the fire control system, measured in the vertical plane through the target speed vector. Positive angles measured upward from the horizontal plane.

Note: 1. Previously called *I*

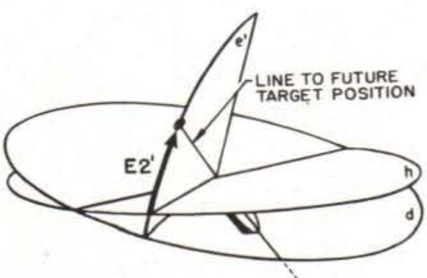
E2



Future Target Elevation

Angle between the horizontal plane and the line to the future target position, measured in the vertical plane through the line to the future target position. Positive angles measured upward from the horizontal plane.

E2′



Future Target Elevation

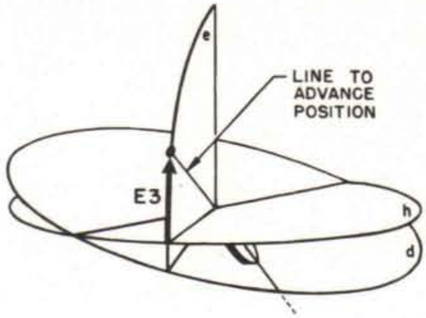
Angle between the horizontal plane and the line to the future target position. measured in the normal plane through the line to the future target position. Positive angles measured upward from the horizontal plane.

E3

Elevation of Advance Position

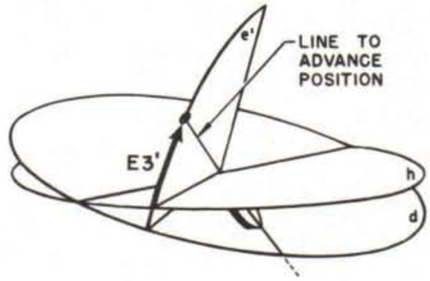
Angle between the horizontal plane and the line to the advance position, measured in the vertical plane through the line to the advance position. Positive angles measured upward from the horizontal plane.

Note: 1. Previously called ***E2***



E3′

Angle between the horizontal plane and the line to the advance position, measured in the normal plane through the line to the advance position. Positive angles measured upward from the horizontal plane.



F

Fuze Setting Order

See *T5*

Target Height — H

See ***Rv***

Rate of Climb — dH

See ***Mv***

dHf

The correction to the rate of climb accounting for the effect of gravity on the projectile.

Note: 1. Now symbolized by enclosing the rate of climb symbol ***DMv*** in parentheses and preceding by modifier ***b***, resulting in ***b(DMv)***

dHfp

The correction to the rate of climb accounting for the effect of gravity and for the effect of parallax.

Note: 1. Now symbolized by enclosing the rate of climb symbol ***DMv*** in parentheses and preceding by modifiers ***b*** and ***p***, resulting in ***pb(DMv)***

Angle of Climb or Dive

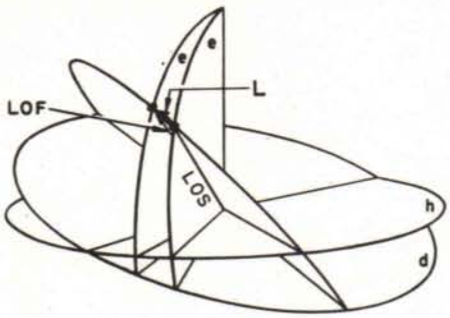
See ***Et***

Windage Jump

Jw

Total angular deviation of the projectile as it leaves the muzzle due to a relative wind velocity at right angles to the line of fire. This is in addition to the blowing of the projectile off its course by the wind.

L



Total Lead Angle

Angle between the line of sight and the line of fire.

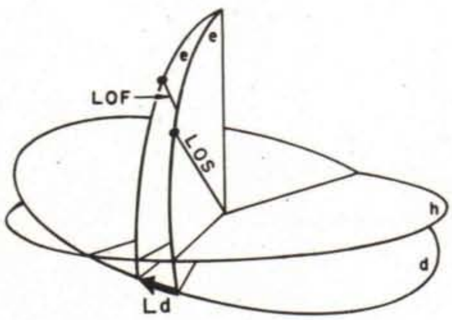
Note: 1. Previously used for level. See ***Ei***

L′

Level

See ***Ei′***

Ld

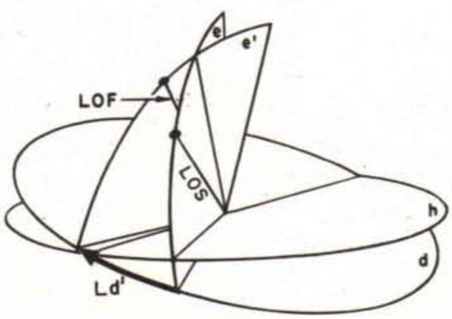


Deck Deflection

Angle between the vertical plane through the line of sight, and the vertical plane through the line of fire, measured in the deck plane from the vertical plane through the line of sight.

Note: 1. Previously called *Dd*

Ld′



Deck Deflection

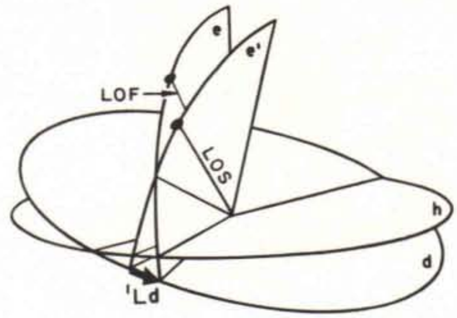
Angle between the vertical plane through the line of sight, and the normal plane through the line of fire, measured in the deck plane from the vertical plane through the line of sight.

Note: 1. Previously called *Dd′*

'Ld

Deck Deflection

Angle between the normal plane through the line of sight, and the vertical plane through the line of fire, measured in the deck plane from the normal plane through the line of sight.

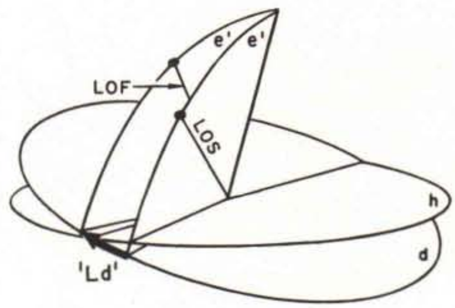


'Ld'

Deck Deflection

Angle between the normal plane through the line of sight, and the normal plane through the line of fire, measured in the deck plane from the normal plane through the line of sight.

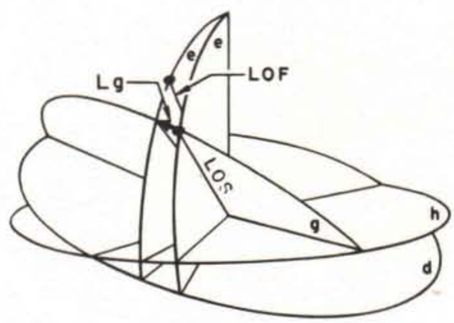
Note: 1. Previously called *D'd*



Lg

Sight Deflection

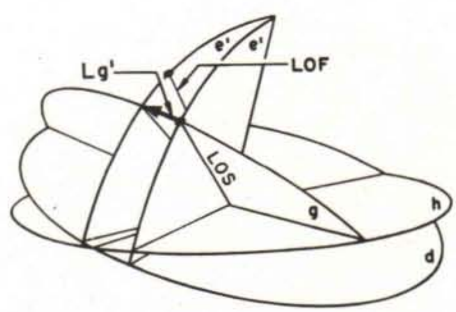
Angle between the line of sight and the vertical plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the horizontal plane.



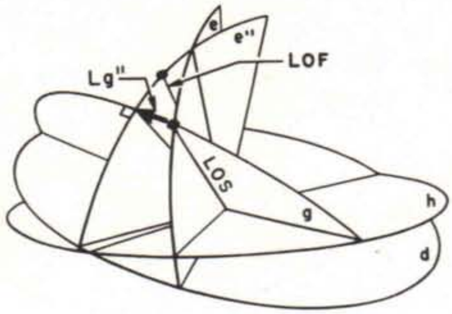
Lg'

Sight Deflection

Angle between the line of sight and the normal plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the horizontal plane.



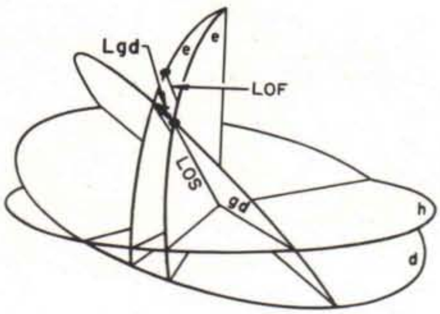
Lg''



Sight Deflection

Angle between the line of sight and the plane through the line of fire perpendicular to the slant plane, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the horizontal plane.

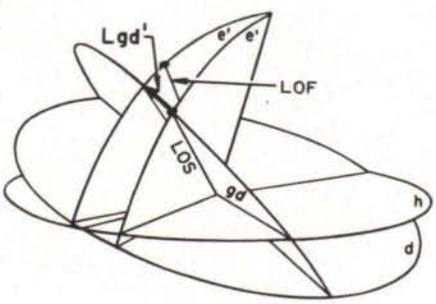
Lgd



Sight Deflection

Angle between the line of sight and the vertical plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the deck plane.

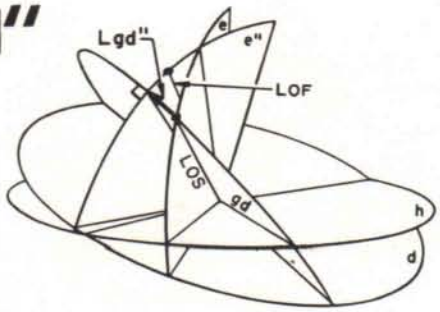
Lgd'



Sight Deflection

Angle between the line of sight and the normal plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the deck plane.

Lgd''



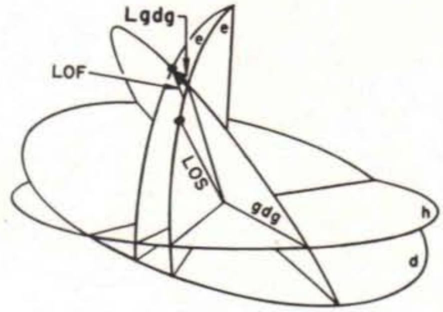
Sight Deflection

Angle between the line of sight and the plane through the line of fire perpendicular to the slant plane, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the deck plane.

Lgdg

Sight Deflection

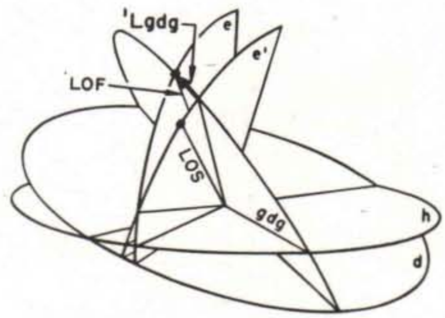
Angle between the line of fire and the vertical plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the gun elevation axis in the deck plane.



'Lgdg

Sight Deflection

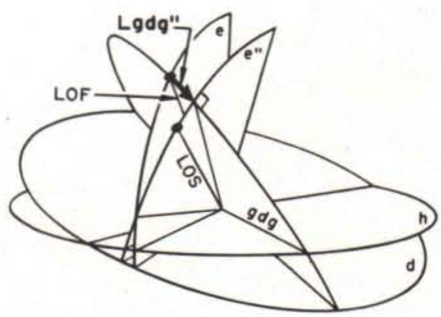
Angle between the line of fire and the normal plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the gun elevation axis in the deck plane.



Lgdg''

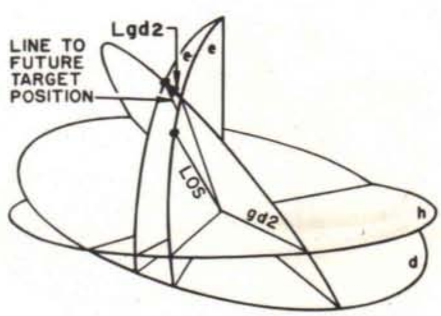
Sight Deflection

Angle between the line of fire and the plane through the line of sight perpendicular to the slant plane, measured from the line of fire in the slant plane through the line of fire and through the gun elevation axis in the deck plane.



Lgd2

Angle between the line to the future target position, and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the deck plane.



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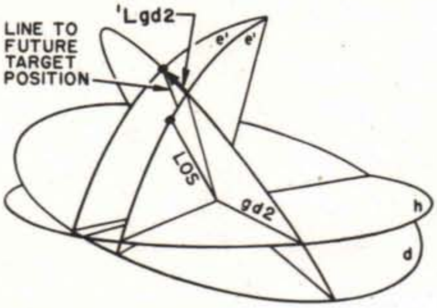
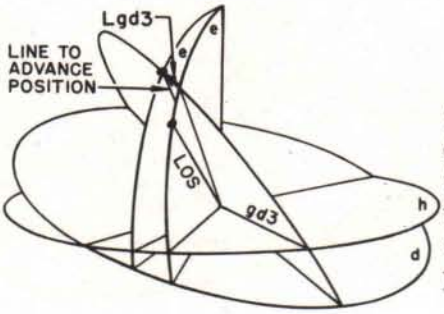
'Lgd2



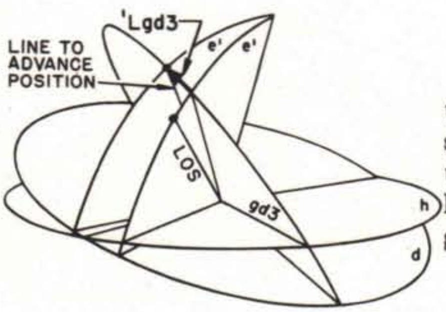
Angle between the line to the future target position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the deck plane.

Lgd3



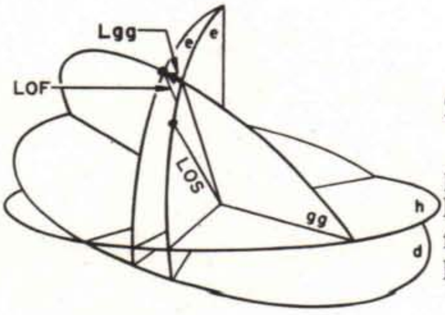
Angle between the line to the advance position, and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the advance position and through the gun elevation axis in the deck plane.

'Lgd3



Angle between the line to the advance position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the advance position and through the gun elevation axis in the deck plane.

Lgg



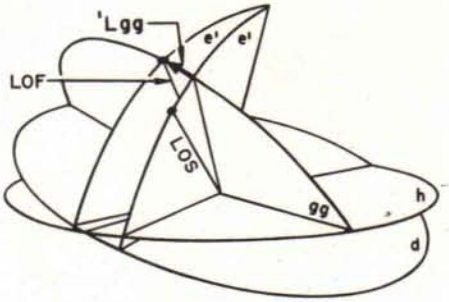
Sight Deflection

Angle between the line of fire, and the vertical plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the gun elevation axis in the horizontal plane.

'Lgg

Sight Deflection

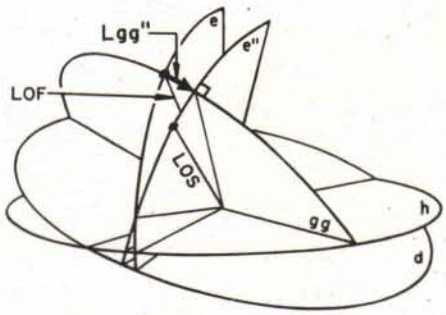
Angle between the line of fire and the normal plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the gun elevation axis in the horizontal plane.



Lgg''

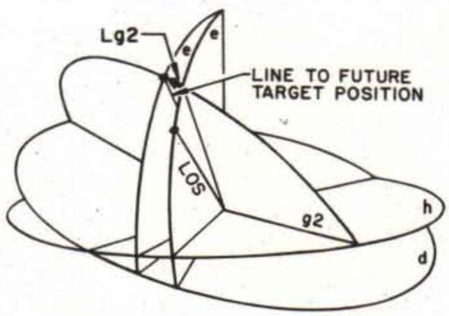
Sight Deflection

Angle between the line of fire and the plane through the line of sight perpendicular to the slant plane, measured from the line of fire in the slant plane through the line of fire and through the gun elevation axis in the horizontal plane.



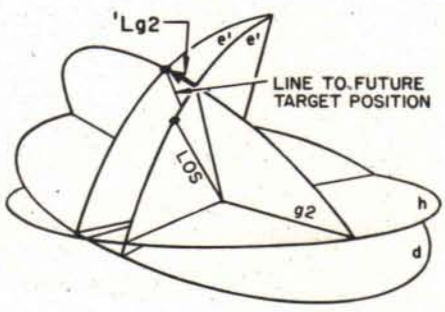
Lg2

Angle between the line to the future target position and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the horizontal plane.

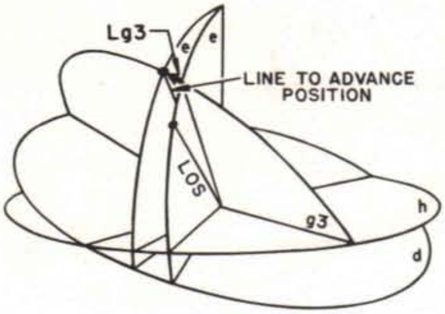


'Lg2

Angle between the line to the future target position and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the horizontal plane.

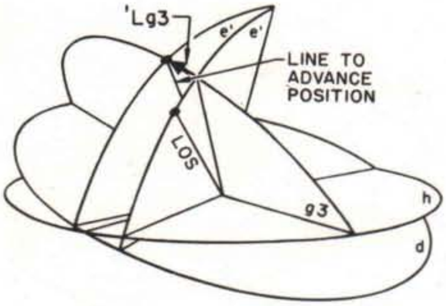


Lg3



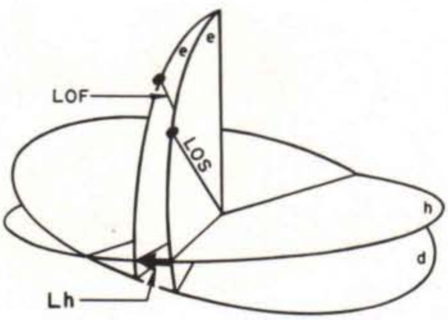
Angle between the line to the advance position, and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the advance position and through the gun elevation axis in the horizontal plane.

'Lg3



Angle between the line to the advance position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the advance position and through the gun elevation axis in the horizontal plane.

Lh

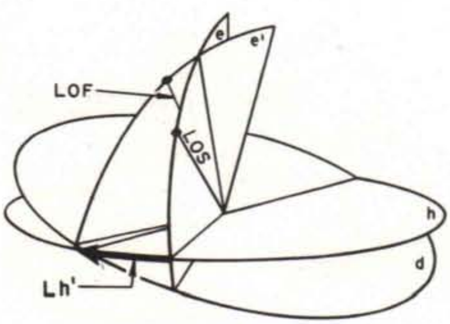


Horizontal Deflection

Angle between the vertical plane through the line of sight and the vertical plane through the line of fire, measured in the horizontal plane from the vertical plane through the line of sight.

Note: 1. Previously called *Dh*

Lh'



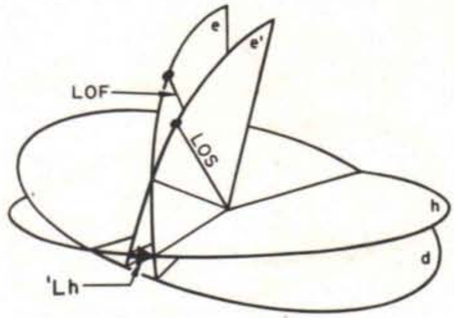
Horizontal Deflection

Angle between the vertical plane through the line of sight and the normal plane through the line of fire, measured in the horizontal plane from the vertical plane through the line of sight.

'Lh

Horizontal Deflection

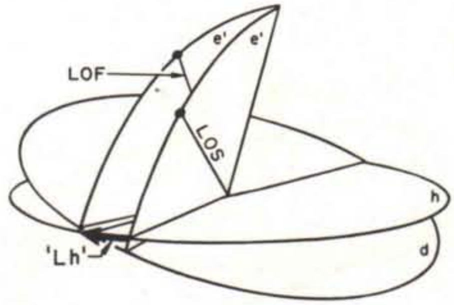
Angle between the normal plane through the line of sight and the vertical plane through the line of fire, measured in the horizontal plane from the normal plane through the line of sight.



'Lh'

Horizontal Deflection

Angle between the normal plane through the line of sight and the normal plane through the line of fire, measured in the horizontal plane from the normal plane through the line of sight.

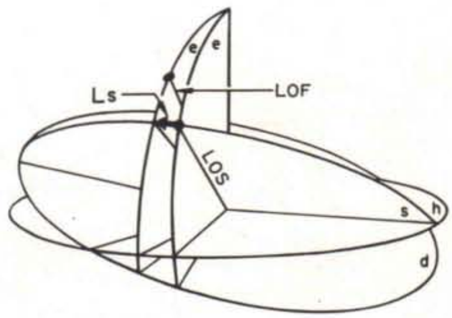


Ls

Sight Deflection

Angle between the line of sight and the vertical plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane.

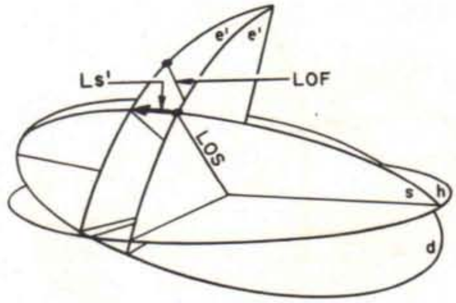
Note: 1. Previously called *Ds*



Ls'

Sight Deflection

Angle between the line of sight and the normal plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane.



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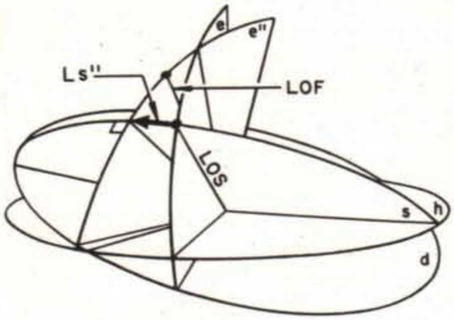
Ls''

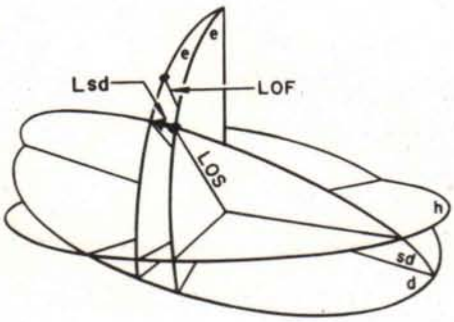


Sight Deflection

Angle between the line of sight and the plane through the line of fire perpendicular to the slant plane, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane.

Note: 1. Previously called *D*

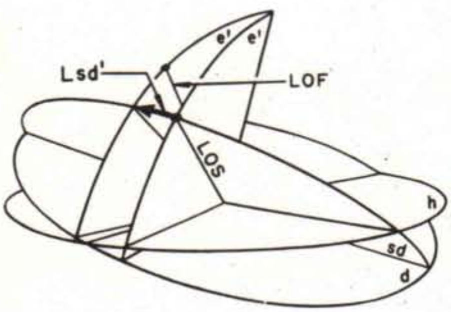
Lsd



Sight Deflection

Angle between the line of sight and the vertical plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the deck plane.

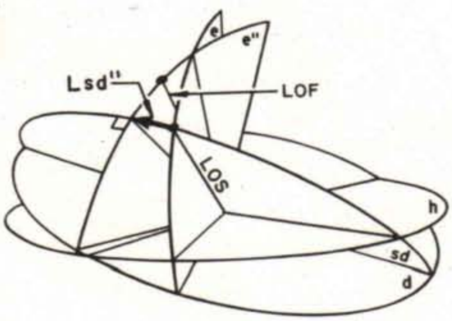
Lsd'



Sight Deflection

Angle between the line of sight and the normal plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the deck plane.

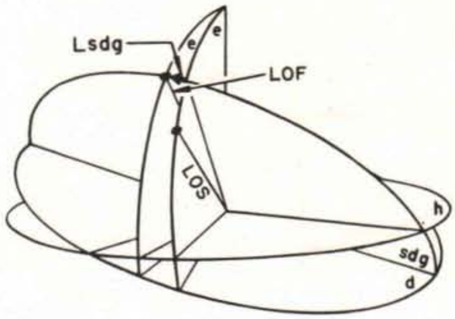
Lsd''



Sight Deflection

Angle between the line of sight and the plane through the line of fire perpendicular to the slant plane, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the deck plane.

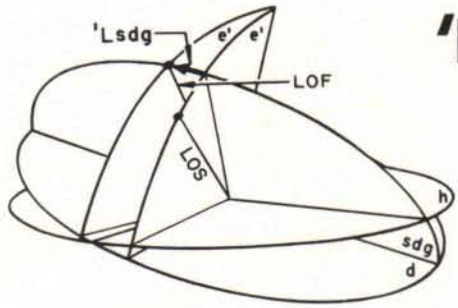
Lsdg



Sight Deflection

Angle between the line of fire and the vertical plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the director elevation axis in the deck plane.

'Lsdg

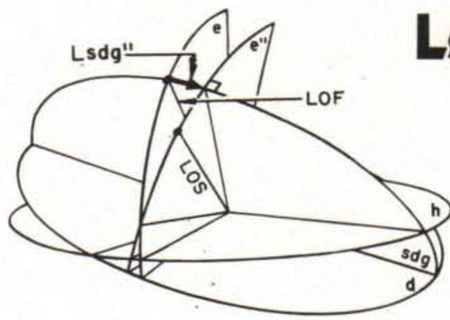


Sight Deflection

Angle between the line of fire and the normal plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the director elevation axis in the deck plane.

Note: 1. Previously called *D's*

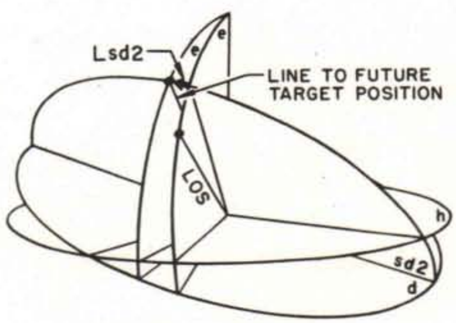
Lsdg''



Sight Deflection

Angle between the line of fire and the plane through the line of sight perpendicular to the slant plane, measured from the line of fire in the slant plane through the line of fire and through the director elevation axis in the deck plane.

Lsd2



Angle between the line to the future target position and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the deck plane.

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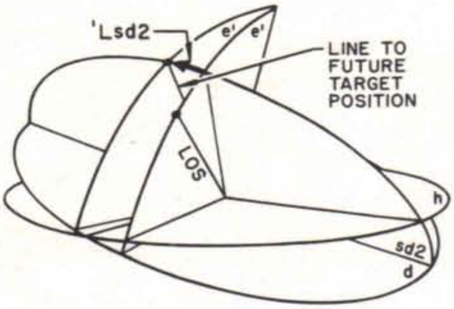
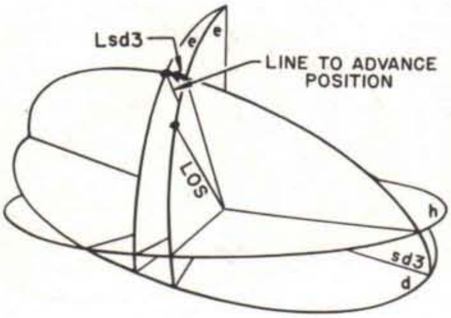
'Lsd2



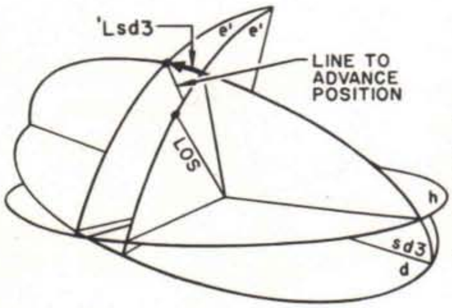
Angle between the line to the future target position and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the deck plane.

Lsd3



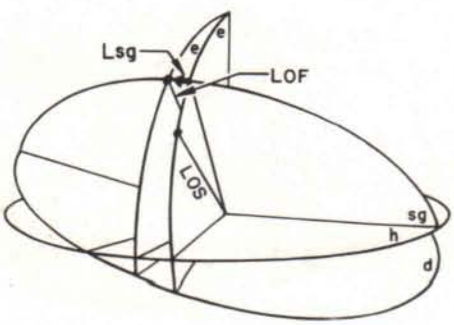
Angle between the line to the advance position and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the advance position and through the director elevation axis in the deck plane.

'Lsd3



Angle between the line to the advance position and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the advance position and through the director elevation axis in the deck plane.

Lsg



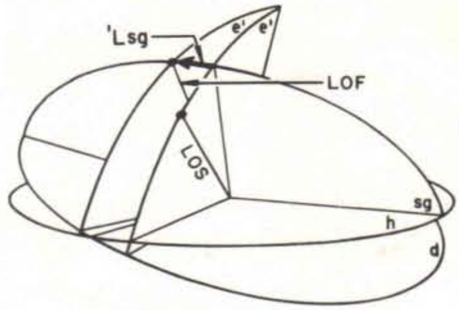
Sight Deflection

Angle between the line of fire and the vertical plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the director elevation axis in the horizontal plane.

'Lsg

Sight Deflection

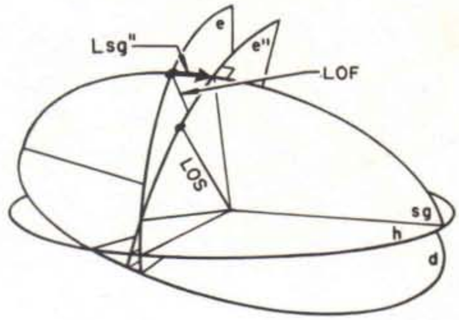
Angle between the line of fire and the normal plane through the line of sight, measured to the line of fire in the slant plane through the line of fire and through the director elevation axis in the horizontal plane.



Lsg"

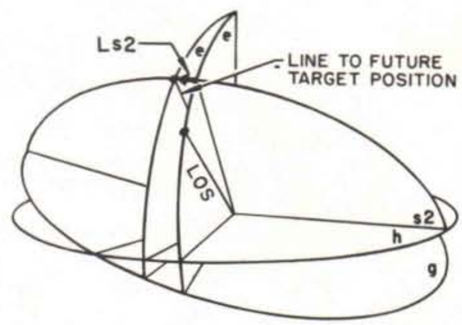
Sight Deflection

Angle between the line of fire and the plane through the line of sight perpendicular to the slant plane, measured from the line of fire in the slant plane through the line of fire and through the director elevation axis in the horizontal plane.



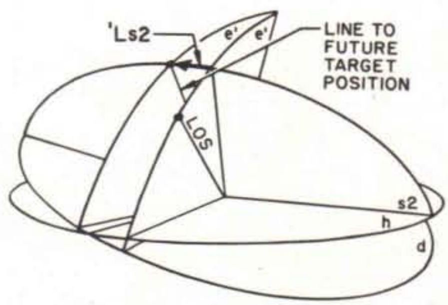
Ls2

Angle between the line to the future target position and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the horizontal plane.

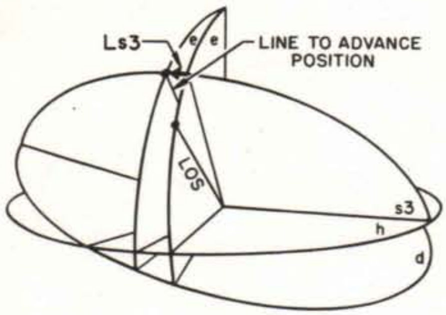


'Ls2

Angle between the line to the future target position and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the horizontal plane.

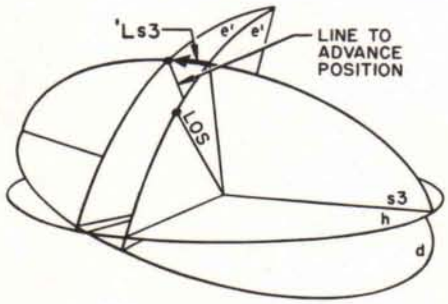


Ls3



Angle between the line to the advance position and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the advance position and through the director elevation axis in the horizontal plane.

'Ls3



Angle between the line to the advance position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the advance position and through the director elevation axis in the horizontal plane.

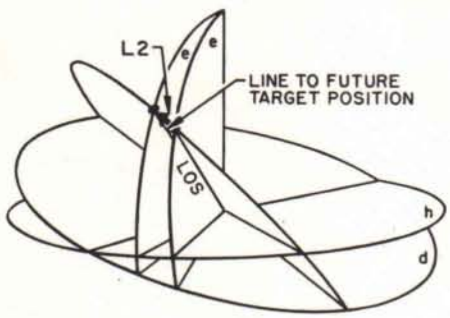
Lz

Trunnion Tilt Correction

Correction to gun train order for the tilting of the gun trunnions due to cross-level.

Note: 1. Previously called *Dz*

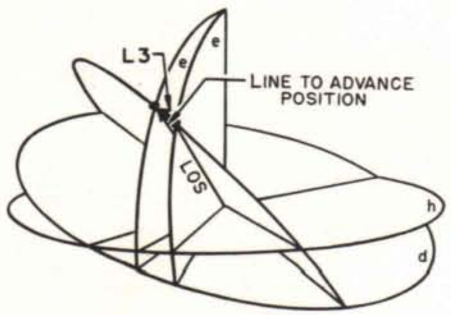
L2



Prediction Plane Lead Angle

Angle between the line of sight, and the line to the future target position.

L3



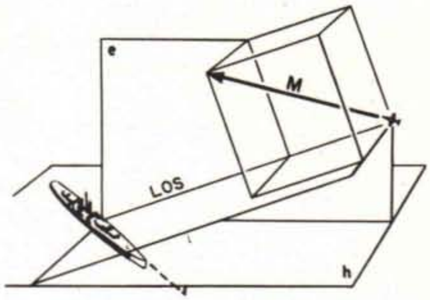
Angle between the line of sight, and the line to the advance position.

The quantities represented by the basic symbol ***M*** are the linear displacement quantities resulting from relative motion, own ship motion, and target motion during the time of flight. To symbolize the rates causing these displacements the linear displacement symbol is preceded by the operator ***D***. ***D*** is the differentiating operator d/dt where the derivative is taken with respect to time at the instant of firing. For example, applying the operator ***D*** to linear displacement in range, ***Mr***, gives range rate, ***DMr***.

M

Total Relative Movement

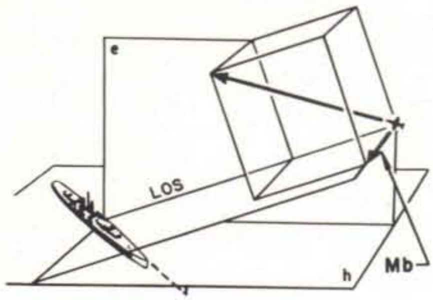
Total linear displacement of the target during the time of flight due to relative motion between own ship and target in the frame used by the fire control system.



Note: 1. Previously used for roll. See ***Zo***

2. To express total linear displacement during the time of flight due to own ship motion, modifier ***o*** is added, resulting in symbol ***Mo***
3. To express total linear displacement during the time of flight due to target motion, modifier ***t*** is added, resulting in symbol ***Mt***
4. To express total linear displacement to advance position, modifier ***3*** is added, resulting in symbol ***M3***
5. To express total linear displacement to aiming position, modifier ***4*** is added, resulting in symbol ***M4***
6. The rate causing this displacement, ***DM***, was previously symbolized *Sr*

Mb

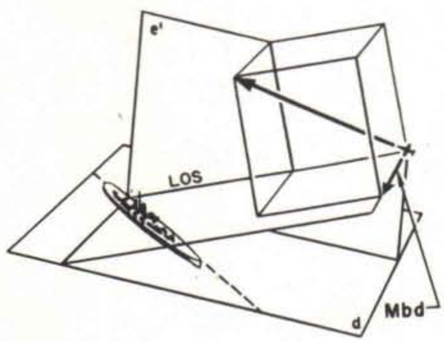


Linear Movement in Bearing

The linear displacement during the time of flight in the horizontal plane perpendicular to the vertical plane through the line of sight, resulting from relative motion between own ship and target in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mbo***
2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mbt***
3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mb3***
4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mb4***
5. The rate causing this displacement, ***DMb*** was previously symbolized *RdBs*

Mbd



Linear Movement in Train

The linear displacement during the time of flight in the deck plane perpendicular to the normal plane through the line of sight, resulting from relative motion between own ship and target in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mbdo***
2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mbdt***
3. To express the same component of displacement to the advance position, modifier ***3*** is added, and symbol is ***Mbd3***
4. To express the same component of displacement to the aiming position, modifier ***4*** is added, and symbol is ***Mbd4***

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Mbdo

See Note 1 under ***Mbd***

Mbdt

See Note 2 under ***Mbd***

Mbd3

See Note 3 under ***Mbd***

Mbd4

See Note 4 under ***Mbd***

Mbo

See Note 1 under ***Mb***

Note: 1. The rate causing this displacement, ***DMbo***, was previously symbolized as *Xo*

Mbt

See Note 2 under ***Mb***

Note: 1. The rate causing this displacement, ***DMbt***, was previously symbolized as *Xt*

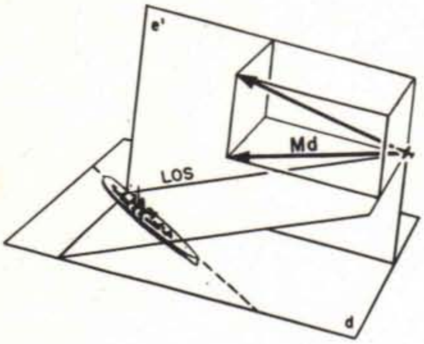
Mb3

See Note 3 under ***Mb***

Mb4

See Note 4 under ***Mb***

Md



Linear Movement in Deck

The linear displacement during the time of flight in the deck and in the normal plane through the relative target speed vector in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier *o* is added, and symbol is ***Mdo***

2. To express the same quantity due to target motion, modifier *t* is added, and symbol is ***Mdt***
3. To express the same component of displacement to the advance position, modifier *3* is added, and symbol is ***Md3***
4. To express the same component of displacement to aiming position, modifier *4* is added, and symbol is ***Md4***

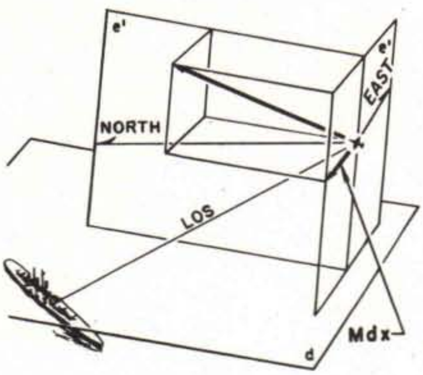
Mdo

See Note 1 under ***Md***

Mdt

See Note 2 under ***Md***

Mdx



The linear displacement during the time of flight in the deck plane and in the East-West normal plane, due to relative motion between own ship and target in the frame used in the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier *o* is added, and symbol is ***Mdxo***

2. To express the same quantity due to target motion, modifier *t* is added, and symbol is ***Mdxt***
3. To express the same component of displacement to advance position, modifier *3* is added, and symbol is ***Mdx3***
4. To express the same component of displacement to aiming position, modifier *4* is added, and symbol is ***Mdx4***

Mdxo

See Note 1 under ***Mdx***

Mdxt

See Note 2 under ***Mdx***

Mdx3

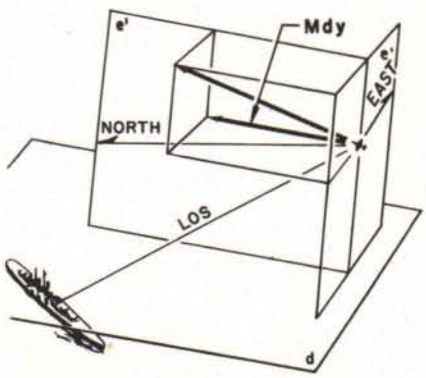
See Note 3 under ***Mdx***

Mdx4

See Note 4 under ***Mdx***

Mdy

The linear displacement during the time of flight in the deck plane and in the North-South normal plane, due to relative motion between own ship and target in the frame used by the fire control system.



Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mdyo***

2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mdyt***

3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mdy3***

4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mdy4***

Mdyo

See Note 1 under ***Mdy***

Mdyt

See Note 2 under ***Mdy***

Mdy3

See Note 3 under ***Mdy***

Mdy4

See Note 4 under ***Mdy***

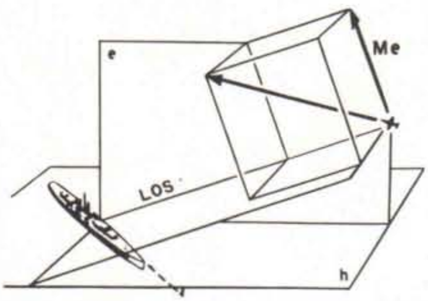
Md3

See Note 3 under ***Md***

Md4

See Note 4 under ***Md***

Me



Linear Movement in Elevation

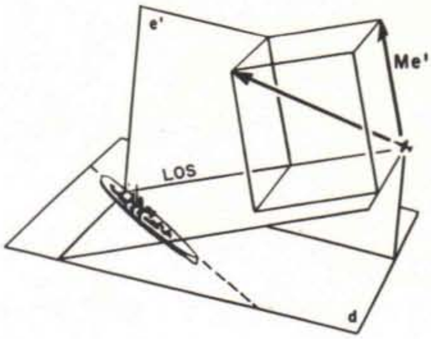
The linear displacement during the time of flight perpendicular to the line of sight in the vertical plane through the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.

Note:
1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Meo***
2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Met***
3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Me3***
4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Me4***
5. The rate causing this displacement, ***DMe***, was previously called ***RdE***

Me′

Linear Movement in Elevation

The linear displacement during the time of flight perpendicular to the line of sight in the normal plane through the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.



Note: 1. To express the same quantity due to own ship motion, modifier *o* is added, and symbol is ***Meo′***
2. To express the same quantity due to target motion, modifier *t* is added, and symbol is ***Met′***
3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Me3′***
4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Me4′***

Meo

See Note 1 under ***Me***

Meo′

See Note 1 under ***Me′***

Met

See Note 2 under ***Me***

Met′

See Note 2 under ***Me′***

Me3

See Note 3 under ***Me***

Me3′

See Note 3 under ***Me′***

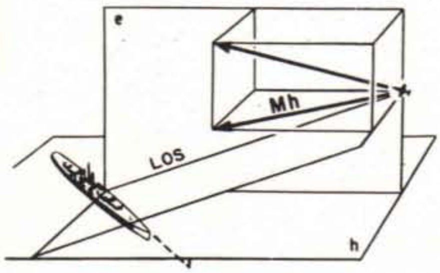
Me4

See Note 4 under ***Me***

Me4′

See Note 4 under ***Me′***

Mh



Linear Movement in Horizontal

The linear displacement during the time of flight in the horizontal plane and in the vertical plane through the relative target speed vector in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mho***
2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mht***
3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mh3***
4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mh4***

Mho

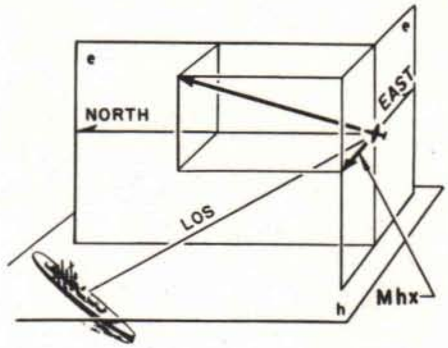
See Note 1 under ***Mh***

Mht

See Note 2 under ***Mh***

Mhx

The linear displacement during the time of flight in the horizontal plane and in the East-West vertical plane, due to relative motion between own ship and target in the frame used by the fire control system.



Note: 1. To express the same quantity due to own ship motion, modifier *o* is added, and symbol is ***Mhxo***

2. To express the same quantity due to target motion, modifier *t* is added, and symbol is ***Mhxt***

3. To express the same component of displacement to advance position, modifier *3* is added, and symbol is ***Mhx3***

4. To express the same component of displacement to aiming position, modifier *4* is added, and symbol is ***Mhx4***

Mhxo

See Note 1 under ***Mhx***

Mhxt

See Note 2 under ***Mhx***

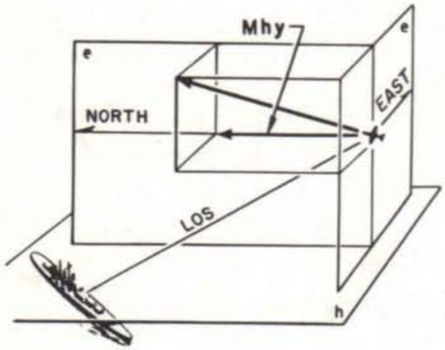
Mhx3

See Note 3 under ***Mhx***

Mhx4

See Note 4 under ***Mhx***

Mhy



The linear displacement during the time of flight in the horizontal plane and in the North-South vertical plane, due to relative motion between own ship and target in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion modifier ***o*** is added, and symbol is ***Mhyo***

2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mhyt***

3. To express the same component of displacement to advance position, modifier ***3*** is added and symbol is ***Mhy3***

4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mhy4***

Mhyo

See Note 1 under ***Mhy***

Mhyt

See Note 2 under ***Mhy***

Mhy3

See Note 3 under ***Mhy***

Mhy4

See Note 4 under ***Mhy***

Mh3

See Note 3 under ***Mh***

See Note 4 under ***Mh*** **Mh4**

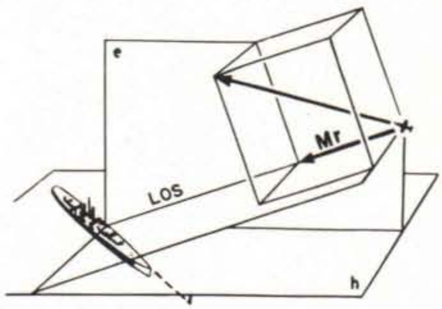
Total Own Ship Movement **Mo**

See Note 2 under ***M***

Mr

Linear Movement in Range

The linear movement during the time of flight along the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.



Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mro***

2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mrt***

3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mr3***

4. To express the same component of displacement to aiming position, modifier ***4*** is added and symbol is ***Mr4***

5. The rate causing this displacement, ***DMr***, was previously called dR

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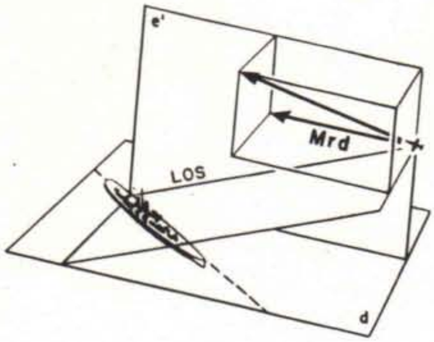
Mrd



Linear Movement in Deck Range

The linear movement during the time of flight in the deck plane and in the normal plane through the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier *o* is added, and symbol is ***Mrdo***
2. To express the same quantity due to target motion, modifier *t* is added, and symbol is ***Mrdt***
3. To express the same component of displacement to advance position, modifier *3* is added, and symbol is ***Mrd3***
4. To express the same component of displacement to aiming position, modifier *4* is added, and symbol is ***Mrd4***

Mrdo

See Note 1 under ***Mrd***

Mrdt

See Note 2 under ***Mrd***

Mrd3

See Note 3 under ***Mrd***

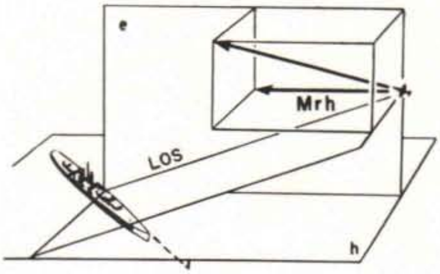
Mrd4

See Note 4 under ***Mrd***

Mrh

Linear Movement in Horizontal Range

The linear movement during the time of flight in the horizontal plane and in the vertical plane through the line of sight, due to relative motion, between own ship and target in the frame used by the fire control system.



Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mrho***

2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mrht***
3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mrh3***
4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mrh4***
5. The rate causing this displacement, ***DMrh*** was previously called *dRh*

Mrho

See Note 1 under ***Mrh***

Note: 1. The rate causing this displacement, ***DMrho,*** was previously symbolized as *Yo*

Mrht

See Note 2 under ***Mrh***

Note: 1. The rate causing this displacement, ***DMrht,*** was previously symbolized as *Yt*

Mrh3

See Note 3 under ***Mrh***

Mrh4

See Note 4 under ***Mrh***

Mro

See Note 1 under ***Mr***

Mrt

See Note 2 under ***Mr***

Mr3

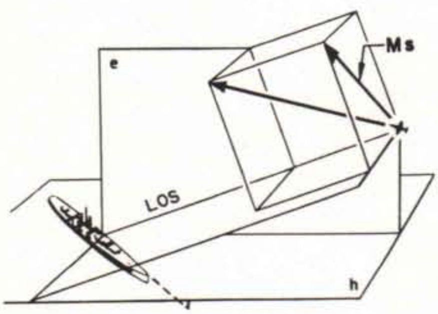
See Note 3 under ***Mr***

Mr4

See Note 4 under ***Mr***

Ms

The total linear displacement during the time of flight perpendicular to the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.



Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mso***

2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mst***

3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Ms3***

4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Ms4***

5. The rate causing this displacement, ***DMs***, was previously symbolized as *RdQ*

Mso

See Note 1 under ***Ms***

Mst

See Note 2 under ***Ms***

Ms3

See Note 3 under ***Ms***

Ms4

See Note 4 under ***Ms***

Mt

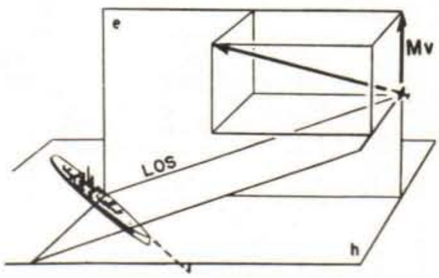
Total Target Movement

See Note 3 under ***M***

Mv

Vertical Linear Movement

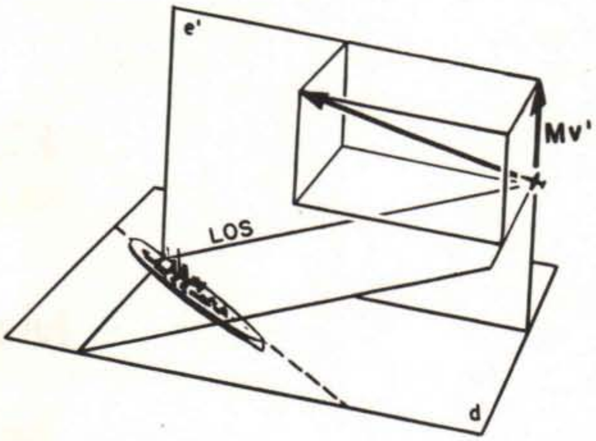
Vertical linear misplacement during the time of flight in the vertical plane through the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.



Note: 1. To express the same quantity due to own ship motion modifier ***o*** is added, and symbol is ***Mvo***

2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Mvt***
3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mv3***
4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mv4***
5. The rate causing this displacement, ***DMv,*** was previously called ***dH***

Mv′



Normal Linear Movement

Normal linear displacement during the time of flight in the normal plane through the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mvo′***

2. To express the same quantity due to target motion, modifier ***t*** is added and symbol is ***Mvt′***
3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mv3′***
4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mv4′***

Mvo

Own Ship Vertical Movement

See Note 1 under ***Mv***

Mvo′

Own Ship Normal Movement

See Note 1 under ***Mv′***

Mvt

Target Vertical Movement

See Note 2 under ***Mv***

Mvt′

Target Normal Movement

See Note 2 under ***Mv′***

Mv3

See Note 3 under ***Mv***

Mv3′

See Note 3 under ***Mv′***

Mv4

See Note 4 under ***Mv***

Mv4′

See Note 4 under ***Mv′***

Mx

Total East-West Linear Movement

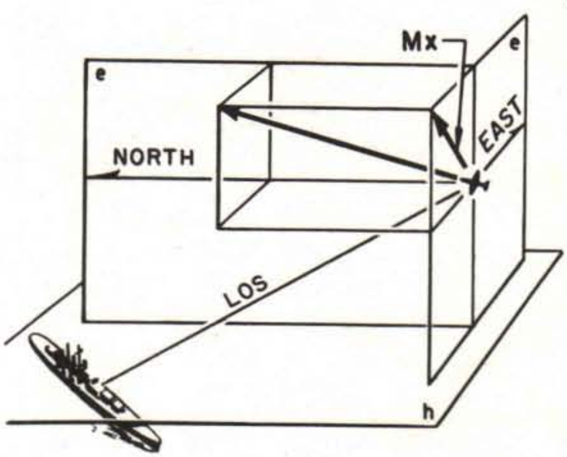
The total linear movement during the time of flight in the East-West vertical plane, due to relative motion between own ship and target in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Mxo***

2. To express the same quantity due to target motion, modifier ***t***, is added, and symbol is ***Mxt***

3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***Mx3***

4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***Mx4***



Mxo

See Note 1 under ***Mx***

Mxt

See Note 2 under ***Mx***

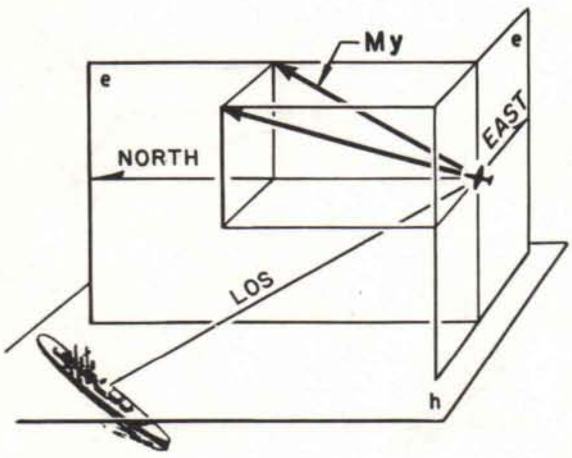
Mx3

See Note 3 under ***Mx***

Mx4

See Note 4 under ***Mx***

My



Total North-South Linear Movement

The total linear movement during the time of flight in the North-South vertical plane, due to relative motion between own ship and target in the frame used by the fire control system.

Note: 1. To express the same quantity due to own ship motion, modifier ***o*** is added, and symbol is ***Myo***

2. To express the same quantity due to target motion, modifier ***t*** is added, and symbol is ***Myt***

3. To express the same component of displacement to advance position, modifier ***3*** is added, and symbol is ***My3***

4. To express the same component of displacement to aiming position, modifier ***4*** is added, and symbol is ***My4***

Myo

See Note 1 under ***My***

Myt

See Note 2 under ***My***

My3

See Note 3 under ***My***

My4

See Note 4 under ***My***

M3

Linear Displacement to Advance Position

See Note 4 under ***M***

M4

Linear Displacement to Aiming Position

See Note 5 under ***M***

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N

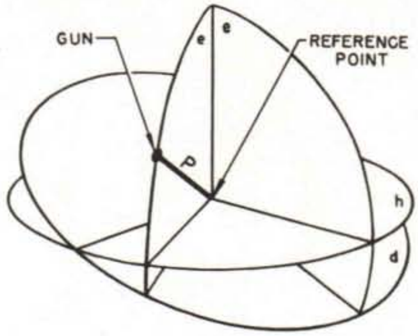
Pitch

See ***Eio***

Gun Parallax Base Length

P

The total distance from the reference point to the gun measured along the gun parallax base line.



Centerline Parallax Displacement

Pbh

See ***Pdo***

Normal Parallax Displacement

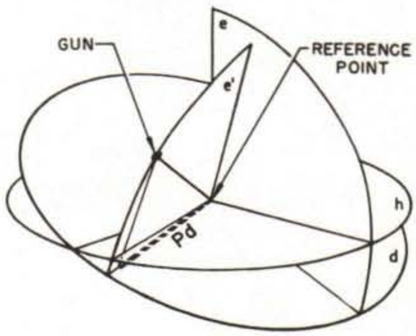
Pbv

See ***Pv′***

Deck Parallax Displacement

Pd

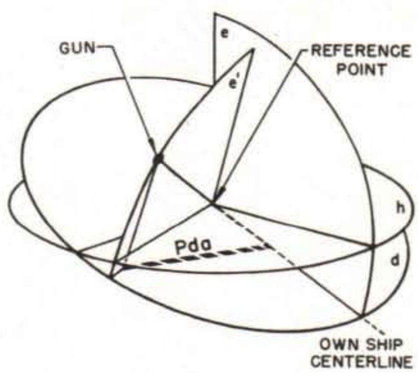
The projection of the parallax base length in the deck plane by a normal plane through the gun parallax base line.



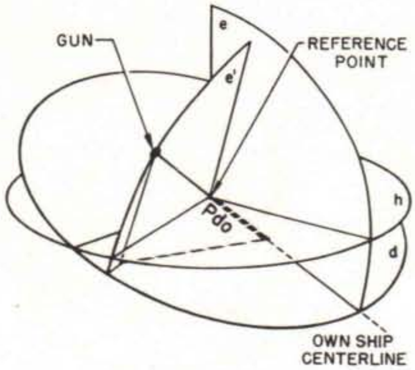
Athwartship Parallax Displacement

Pda

The component of gun parallax base length in the deck plane perpendicular to the normal plane through own ship centerline.



Pdo

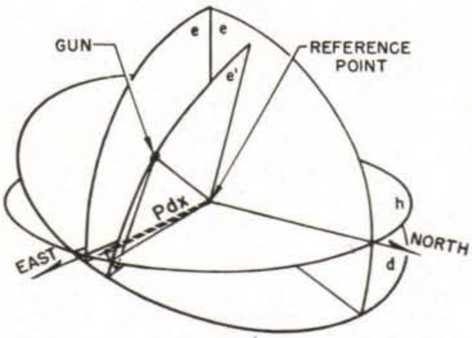


Centerline Parallax Displacement

The component of gun parallax base length along own ship centerline.

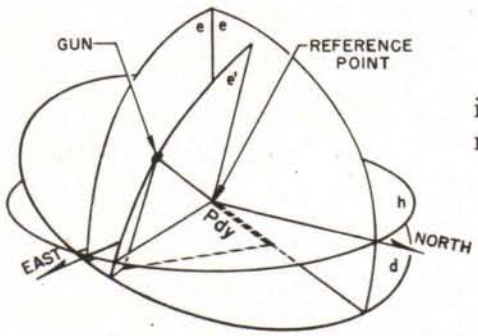
Note: 1. Previously called *Pbh*

Pdx



The component of gun parallax base length in the deck plane and in the East-West normal plane.

Pdy



The component of gun parallax base length in the deck plane and in the North-South normal plane.

Pe

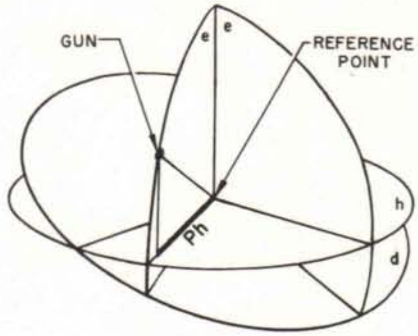
See ***pl(Edg')v***

Ph

Horizontal Parallax Displacement

The projection of the parallax base length in the horizontal plane by a vertical plane through the gun parallax base line.

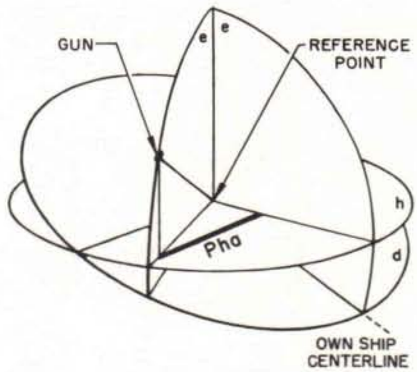
Note: 1. Previously used for Unit Parallax. See ***pl*(*Bdg'*)**



Pha

Athwartship Parallax Displacement

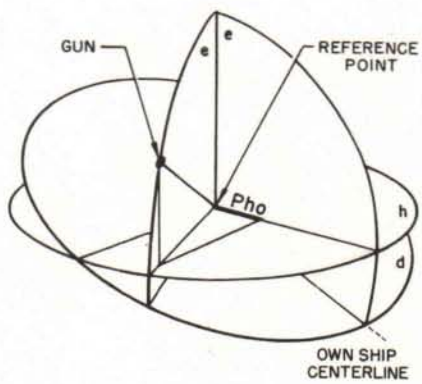
The component of gun parallax base length in the horizontal plane perpendicular to the vertical plane through own ship centerline.



Pho

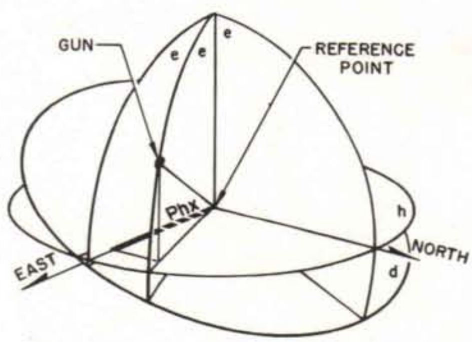
Centerline Parallax Displacement

The component of gun parallax base length in the horizontal plane and in the vertical plane through own ship centerline.

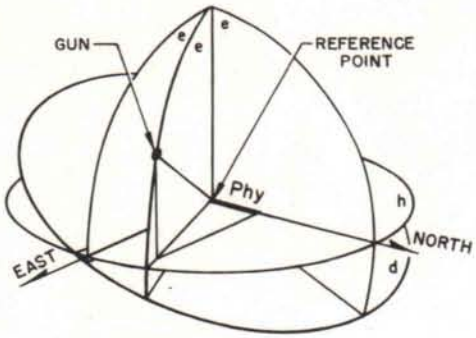


Phx

The component of gun parallax base length in the horizontal plane and in the East-West vertical plane.

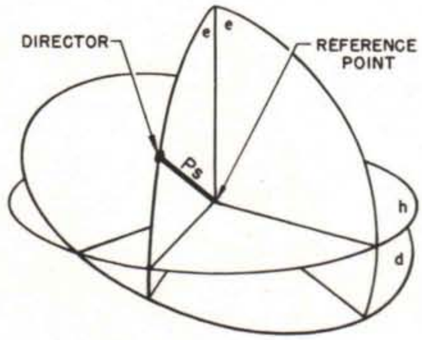


Phy



The component of gun parallax base length in the horizontal plane and in the North-South vertical plane.

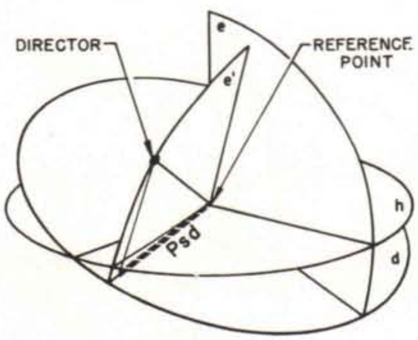
Ps



Director Parallax Base Length

The total distance from the reference point to the director measured along the director parallax base line.

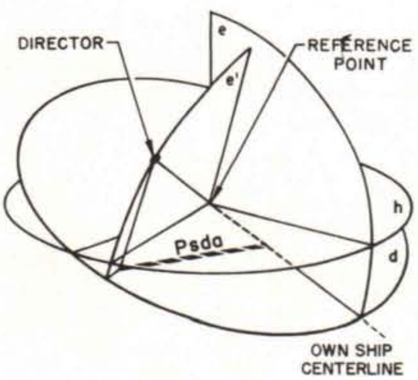
Psd



Deck Parallax Displacement

The projection of the director parallax base length in the deck plane by a normal plane through the director parallax base line.

Psda



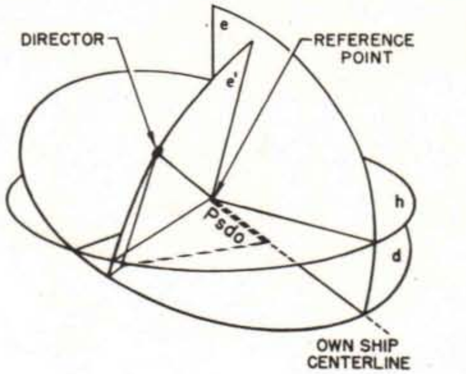
Athwartship Parallax Displacement

The component of director parallax base length in the deck plane perpendicular to the normal plane through own ship centerline.

Psdo

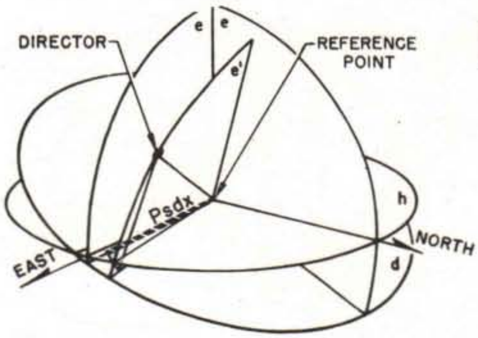
Centerline Parallax Displacement

The component of director parallax base length along own ship centerline.



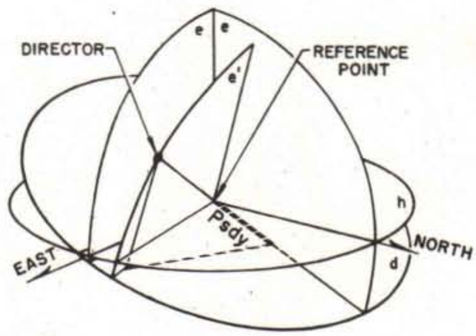
Psdx

The component of director parallax base length in the deck plane and in the East-West normal plane.



Psdy

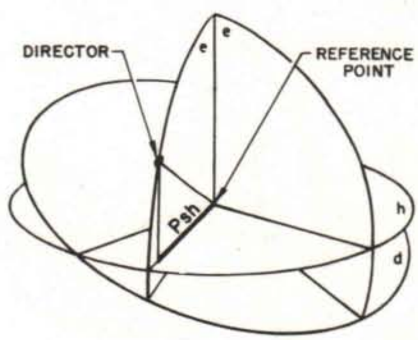
The component of director parallax base length in the deck plane and in the North-South normal plane.



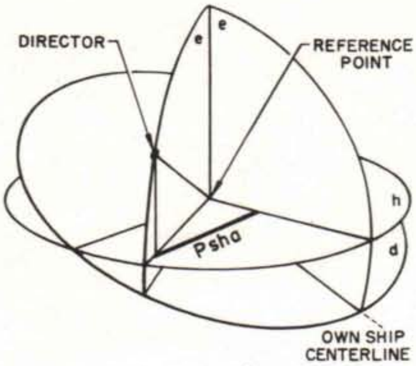
Psh

Horizontal Parallax Displacement

The projection of the director parallax, base length in the horizontal plane by a vertical plane through the director parallax base line.



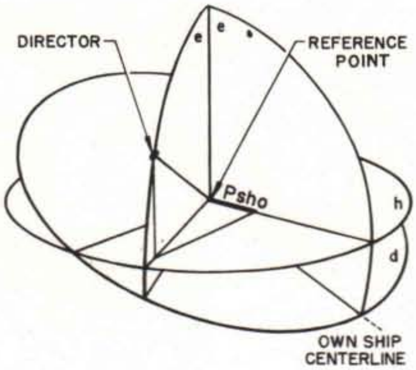
Psha



Athwartship Parallax Displacement

The component of director parallax base length in the horizontal plane perpendicular to the vertical plane through own ship centerline.

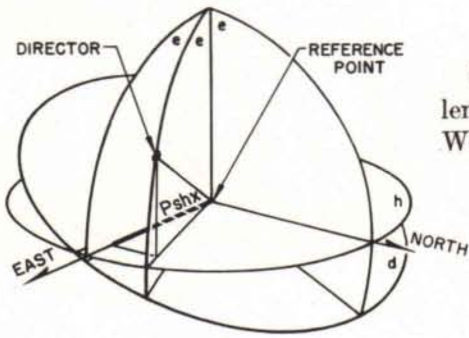
Psho



Centerline Parallax Displacement

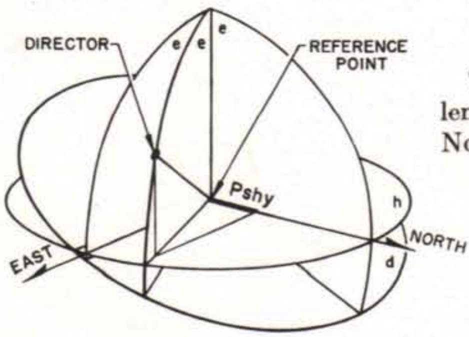
The component of director parallax base length in the horizontal plane and in the vertical plane through own ship centerline.

Pshx



The component of director parallax base length in the horizontal plane and in the East-West vertical plane.

Pshy

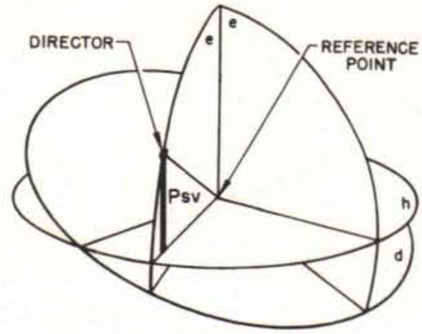


The component of director parallax base length in the horizontal plane and in the North-South vertical plane.

Psv

Vertical Parallax Displacement

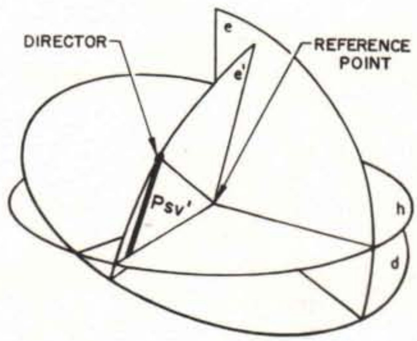
Vertical component of director parallax base length measured from the horizontal plane in the vertical plane through the director parallax base line.



Psv'

Normal Parallax Displacement

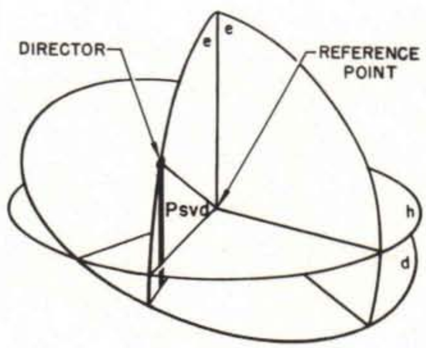
Normal component of director parallax base length measured from the horizontal plane in the normal plane through the director parallax base line.



Psvd

Vertical Parallax Displacement

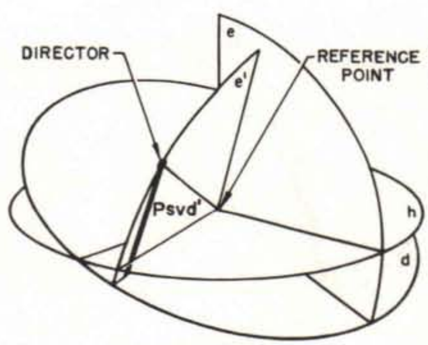
Vertical component of director parallax base length measured from the deck plane in the vertical plane through the director parallax base line.



Psvd'

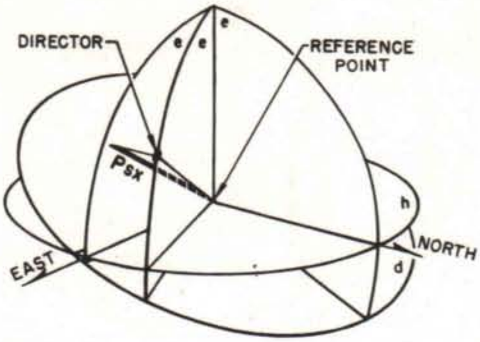
Normal Parallax Displacement

Normal component of director parallax base length measured from the deck plane in the normal plane through the director parallax base line.



891927 O—5

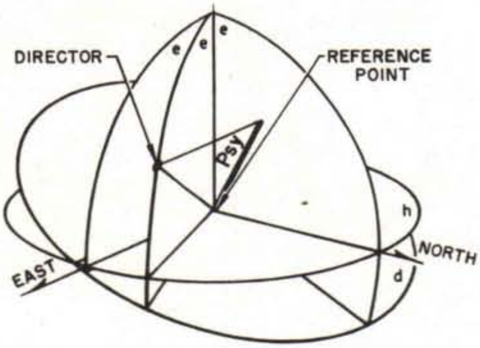
Psx



East-West Parallax Displacement

The projection of the director parallax base length in the East-West vertical plane.

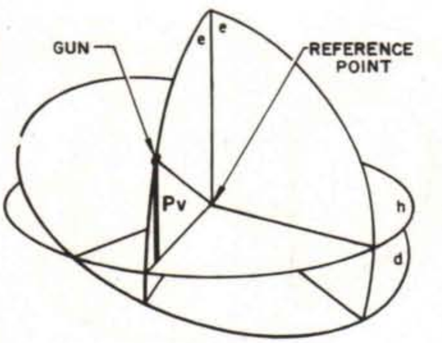
Psy



North-South Parallax Displacement

The projection of the director parallax base length in the North-South vertical plane.

Pv

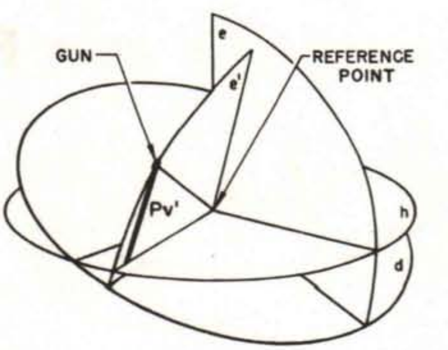


Vertical Parallax Displacement

Vertical component of gun parallax base length measured from the horizontal plane in the vertical plane through the gun parallax base line.

Note: 1. Previously used for elevation parallax due to horizontal base. See ***pl*(*Edg'*)*h***

Pv'



Normal Parallax Displacement

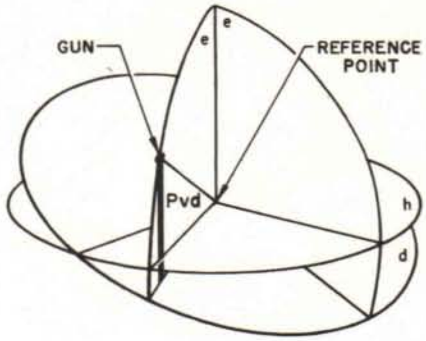
Normal component of gun parallax base length measured from the horizontal plane in the vertical plane through the gun parallax base line.

Note: 1. Previously called *Pbv.*

Pvd

Vertical Parallax Displacement

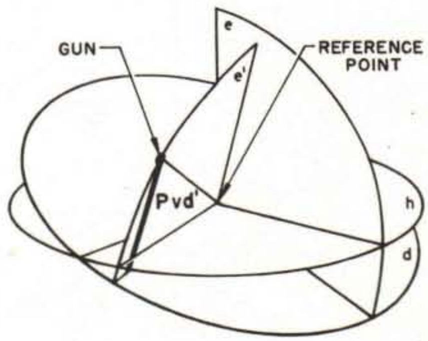
Vertical component of gun parallax base length measured from the deck plane in the vertical plane through the gun parallax base line.



Pvd'

Normal Parallax Displacement

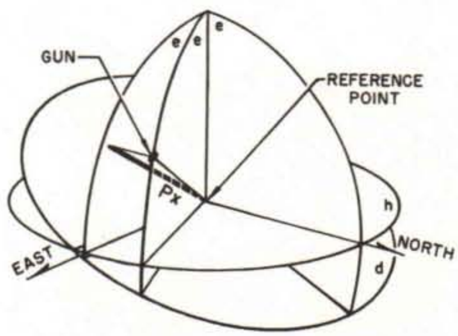
Normal component of gun parallax base length measured from the deck plane in the normal plane through the gun parallax base line.



Px

East-West Parallax Displacement

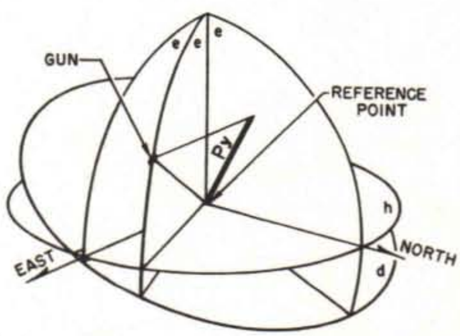
The projection of the gun parallax base length in the East-West vertical plane.



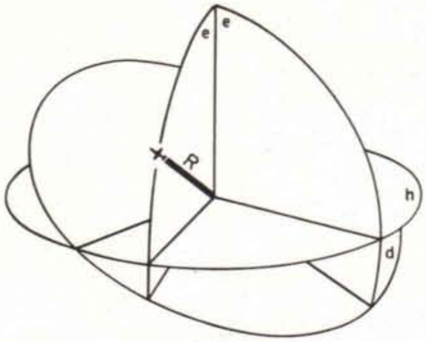
Py

North-South Parallax Displacement

The projection of the gun parallax base length in the North-South vertical plane.



R



Present Range

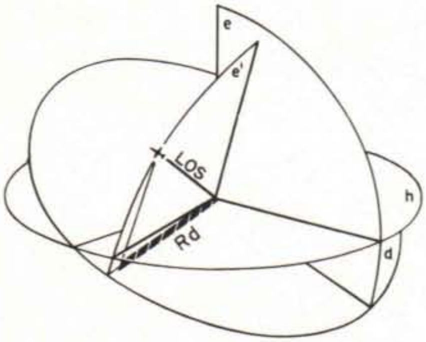
The distance from own ship to target measured along the line of sight.

dR

Range Rate

See ***Mr***

Rd



Deck Range

The projection of present range in the deck plane by a normal plane through the line of sight.

Note: 1. To express the same component of future range, modifier ***2*** is added and symbol is ***Rd2***
2. To express the same component of advance range, modifier ***3*** is added, and symbol is ***Rd3***
3. To express the same component of aiming range, modifier ***4*** is added, and symbol is ***Rd4***

RdBs

Linear Deflection Rate

See Note 5 under ***Mb***

RdBsf

The correction to linear traverse rate accounting for drift.

Note: 1. Now symbolized by enclosing the linear traverse rate, ***DMb***, in parentheses and preceding by modifier ***b***, resulting in ***b***(***DMb***)

RdBstfw

The linear traverse rate adjusted for all effects to the aiming position.

Note: 1. Now symbolized as ***DMb4***

RdBsw

The correction to linear traverse rate accounting for the effect of wind.

Note: 1. Now symbolized as ***w***(***DMb***)

Linear Elevation Rate **RdE**

See Note 5 under ***Me***

RdEfp

The correction to linear elevation rate accounting for the effect of gravity and parallax.

Note: 1. Now symbolized as ***pb(DMe)***

RdEtfpw

Linear elevation rate adjusted for all effects to the aiming position.

Note: 1. Now symbolized as ***DMe4***

RdEw

The correction to linear elevation rate accounting for the effect of wind.

Note: 1. Now symbolized as ***w(DMe)***

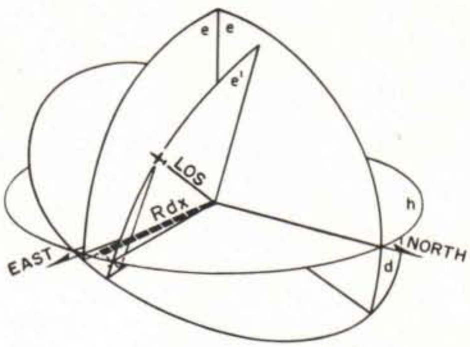
Total Cross Rate **RdQ**

See Note 5 under ***Ms***

East-West Deck Range **Rdx**

The component of present range in the deck plane and in the East-West normal plane.

Note: 1. To express the same component of future range, modifier ***2*** is added, and symbol is ***Rdx2***
2. To express the same component of advance range, modifier ***3*** is added, and symbol is ***Rdx3***
3. To express the same component of aiming range, modifier ***4*** is added, and symbol is ***Rdx4***



Deck East-West Future Range **Rdx2**

See Note 1 under ***Rdx***

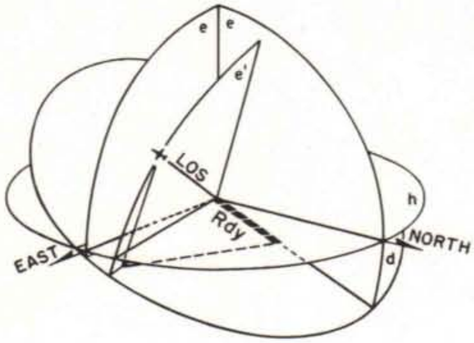
Deck East-West Advance Range **Rdx3**

See Note 2 under ***Rdx***

Deck East-West Aiming Range **Rdx4**

See Note 3 under ***Rdx***

Rdy



North-South Deck Range

The component of present range in the deck plane and in the North-South normal plane.

Note: 1. To express the same component of future range, modifier *2* is added, and symbol is ***Rdy2***
2. To express the same component of advance range, modifier *3* is added, and symbol is ***Rdy3***
3. To express the same component of aiming range, modifier *4* is added, and symbol is ***Rdy4***

Rdy2

Deck North-South Future Range

See Note 1 under ***Rdy***

Rdy3

Deck North-South Advance Range

See Note 2 under ***Rdy***

Rdy4

Deck North-South Aiming Range

See Note 3 under ***Rdy***

Rd2

Deck Future Range

See Note 1 under ***Rd***

Rd3

Deck Advance Range

See Note 2 under ***Rd***

Rd4

Deck Aiming Range

See Note 3 under ***Rd***

Rf

Future Range

See ***R2***

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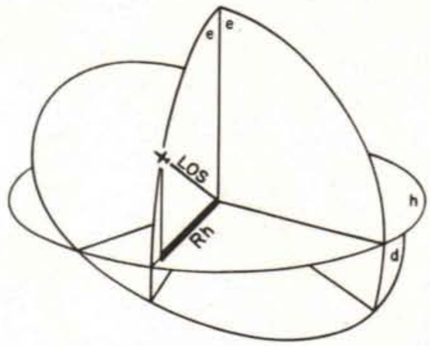
Rh

Horizontal Range

Projection of present range in the horizontal plane by a vertical plane through the line of sight.

Note: 1. To express the same component of future range, modifier *2* is added, and symbol is ***Rh2***
2. To express the same component of advance range, modifier *3* is added, and symbol is ***Rh3***
3. To express the same component of aiming range, modifier *4* is added, and symbol is ***Rh4***



dRh

Horizontal Range Rate

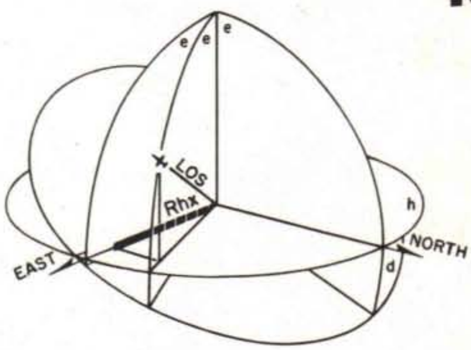
See Note 5 under ***Mrh***

Rhx

East-West Horizontal Range

The component of present range in the horizontal plane and in the East-West vertical plane.

Note: 1. To express the same component of future range, modifier *2* is added, and symbol is ***Rhx2***
2. To express the same component of advance range, modifier *3* is added, and symbol is ***Rhx3***
3. To express the same component of aiming range, modifier *4* is added, and symbol is ***Rhx4***



Horizontal East-West Future Range

See Note 1 under ***Rhx***

Rhx2

Horizontal East-West Advance Range

See Note 2 under ***Rhx***

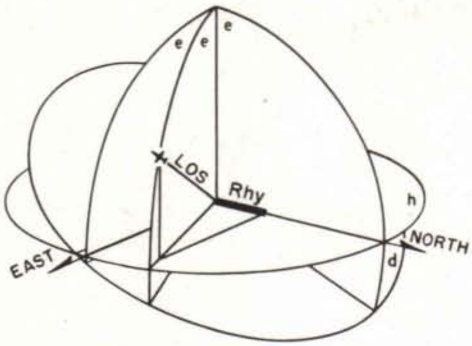
Rhx3

Horizontal East-West Aiming Range

See Note 3 under ***Rhx***

Rhx4

Rhy



North-South Horizontal Range

The component of present range in the horizontal plane and in the North-South vertical plane.

Note: 1. To express the same component of future range, modifier ***2*** is added, and symbol is ***Rhy2***

2. To express the same component of advance range, modifier ***3*** is added, and symbol is ***Rhy3***

3. To express the same component of aiming range, modifier ***4*** is added, and symbol is ***Rhy4***

Rhy2

Horizontal North-South Future Range

See Note 1 under ***Rhy***

Rhy3

Horizontal North-South Advance Range

See Note 2 under ***Rhy***

Rhy4

Horizontal North-South Aiming Range

See Note 3 under ***Rhy***

Rh2

Horizontal Future Range

See Note 1 under ***Rh***

Rh3

Horizontal Advance Range

See Note 2 under ***Rh***

Rh4

Horizontal Aiming Range

See Note 3 under ***Rh***

R_j

Range Spot

Note: 1. Now symbolized as ***q***(***R3***)

Rm

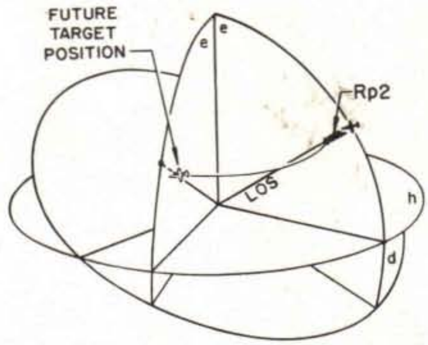
The correction applied to range prediction to account for changes in initial velocity.

Note: 1. Now symbolized as ***u*(*Rp*)**

Rp2

The difference between present range and future range.

Note: 1. Previously symbolized as *Rt*

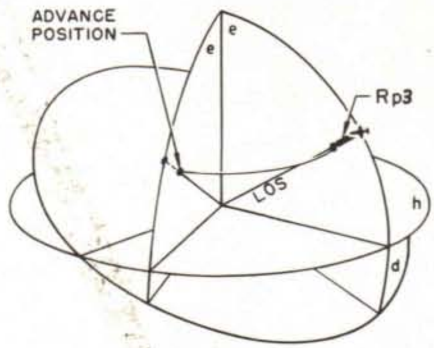


Rp3

Range Prediction

The difference between present range and advance range.

Note: 1. Previously called *Rtwm*



Rt

See Note 1 under ***Rp2***

dRtw

Range rate corrected for the effect of wind.

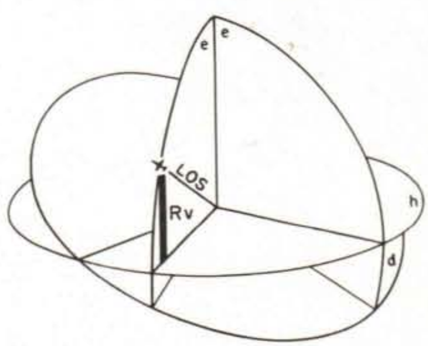
Note: 1. Now symbolized as **(*DMr*) *w***

Rv

Target Height

The height of the target above the horizontal plane measured in the vertical plane through the line of sight.

Note: 1. Previously called *H*
2. To express the same component of future range, modifier ***2*** is added, and symbol is ***Rv2***
3. To express the same component of advance range, modifier ***3*** is added, and symbol is ***Rv3***
4. To express the same component of aiming range, modifier ***4*** is added, and symbol is ***Rv4***



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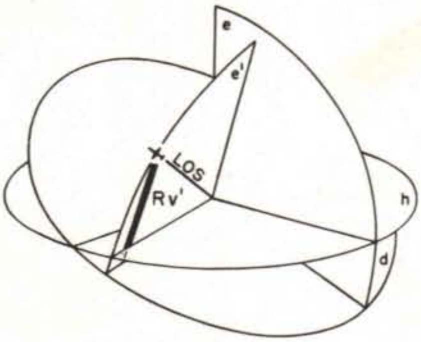
Rv′

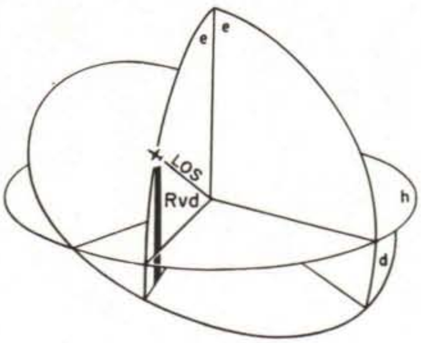


Target Height

The height of the target above the horizontal plane measured in the normal plane through the line of sight.

Note: 1. To express the same component of future range, modifier *2* is added, and symbol is ***Rv2′***
2. To express the same component of advance range, modifier *3* is added, and symbol is ***Rv3′***
3. To express the same component of aiming range, modifier *4* is added, and symbol is ***Rv4′***

Rvd

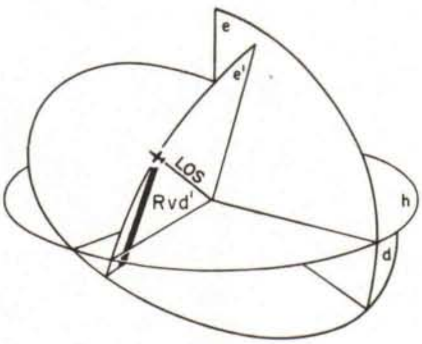


Target Height

The height of the target above the deck plane measured in the vertical plane through the line of sight.

Note: 1. To express the same component of future range, modifier *2* is added, symbol is ***Rvd2***
2. To express the same component of advance range, modifier *3* is added, and symbol is ***Rvd3***
3. To express the same component of aiming range, modifier *4* is added, and symbol is ***Rvd4***

Rvd′



Target Height

The height of the target above the deck plane measured in the normal plane through the line of sight.

Note: 1. To express the same component of future range, modifier *2* is added, and symbol is ***Rvd2′***
2. To express the same component of advance range, modifier *3* is added, and symbol is ***Rvd3′***
3. To express the same component of aiming range, modifier *4* is added, and symbol is ***Rvd4′***

Rvd2

Height of Future Target Position

See Note 1 under ***Rvd***

Rvd2′

Height of Future Target Position

See Note 1 under ***Rvd′***

Rvd3

Height of Advance Position

See Note 2 under ***Rvd***

Height of Advance Position **Rvd3′**
See Note 2 under ***Rvd′***

Height of Aiming Position **Rvd4**
See Note 3 under ***Rvd***

Height of Aiming Position **Rvd4′**
See Note 3 under ***Rvd′***

Height of Future Target Position **Rv2**
See Note 2 under ***Rv***

Height of Future Target Position **Rv2′**
See Note 1 under ***Rv′***

Height of Advance Position **Rv3**
See Note 3 under ***Rv***

Height of Advance Position **Rv3′**
See Note 2 under ***Rv′***

Height of Aiming Position **Rv4**
See Note 4 under ***Rv***

Height of Aiming Position **Rv4′**
See Note 3 under ***Rv′***

Rw

The correction to range prediction to account for wind.

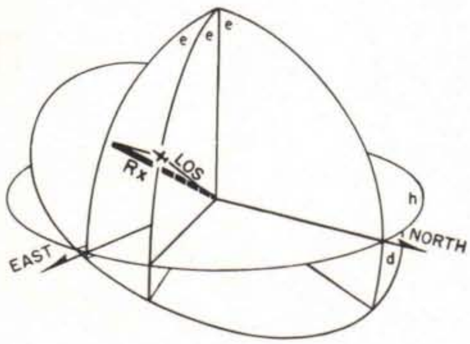
Note: 1. Now called ***W(Rp)***

dRw

The correction to range rate to account for wind.

Note: 1. Now called ***w(DMr)***

Rx



East-West Range

The projection of present range in the East-West vertical plane.

Note: 1. To express the same component of future range, modifier ***2*** is added, and symbol is ***Rx2***
2. To express the same component of advance range, modifier ***3*** is added, and symbol is ***Rx3***
3. To express the same component of aiming range, modifier ***4*** is added, and symbol is ***Rx4***

Rx2

East-West Future Range

See Note 1 under ***Rx***

Rx3

East-West Advance Range

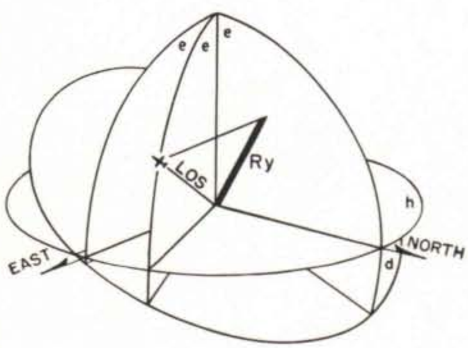
See Note 2 under ***Rx***

Rx4

East-West Aiming Range

See Note 3 under ***Rx***

Ry



North-South Range

The projection of present range in the North-South vertical plane.

Note: 1. To express the same component of future range, modifier ***2*** is added, and symbol is ***Ry2***
2. To express the same component of advance range, modifier ***3*** is added, and symbol is ***Ry3***
3. To express the same component of aiming range, modifier ***4*** is added, and symbol is ***Ry4***

Ry2

North-South Future Range

See Note 1 under ***Ry***

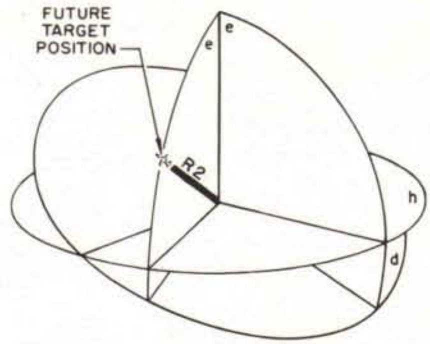
North-South Advance Range **Ry3**

See Note 2 under ***Ry***

North-South Aiming Range **Ry4**

See Note 3 under ***Ry***

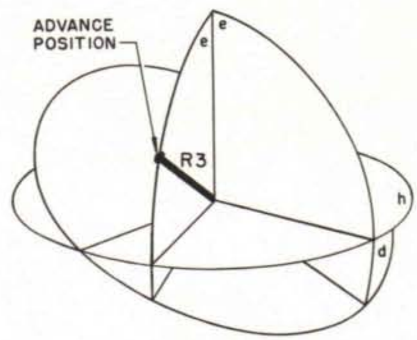
Future Range **R2**



The distance from own ship to future target position measured along the line to the future target position.

Note: 1. Previously called *Rf*
2. Previously used for advance range. See ***R3***

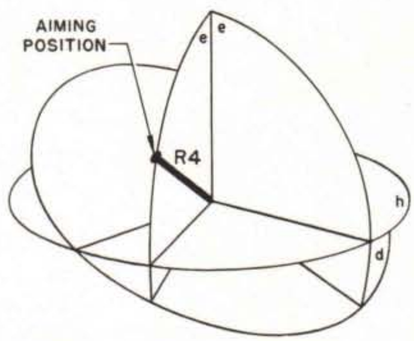
Advance Range **R3**



The distance from own ship to the advance position measured along the line to the advance position.

Note: 1. Previously called *R2*

Aiming Range **R4**



The distance from own ship to the aiming position measured along the line of fire.

Fuze Range **R5**

Range used in the computation of fuze setting order. Advance range plus change in range during dead time.

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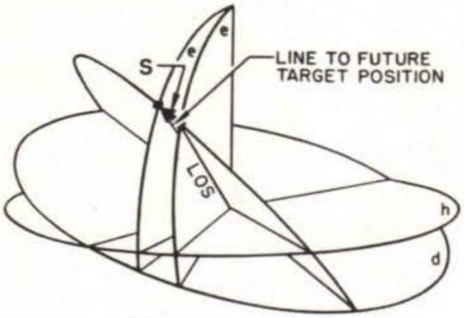
S

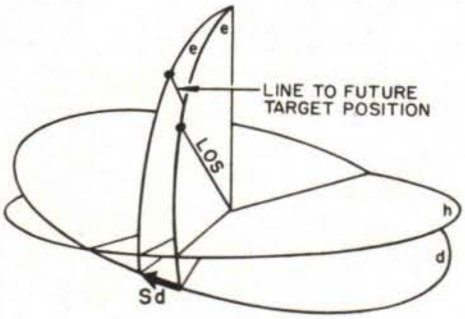


Total Angular Movement

The total angle between the line of sight and the line to the future target position.

Note: 1. Previously used for target speed. See ***Mt***

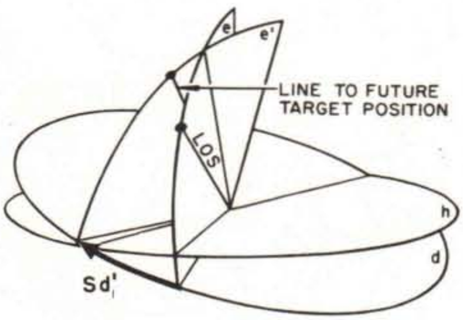
Sd



Deck Angular Movement

The angle between the vertical plane through the line of sight, and the vertical plane through the line to the future target position, measured in the deck plane from the vertical plane through the line of sight.

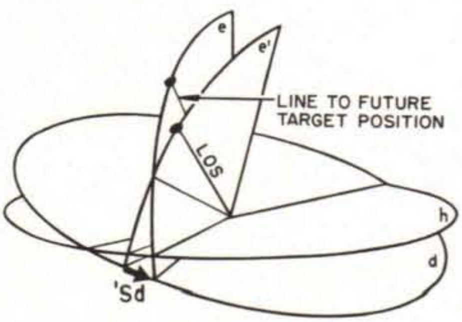
Sd'



Deck Angular Movement

The angle between the vertical plane through the line of sight, and the normal plane through the line to the future target position, measured in the deck plane from the vertical plane through the line of sight.

'Sd



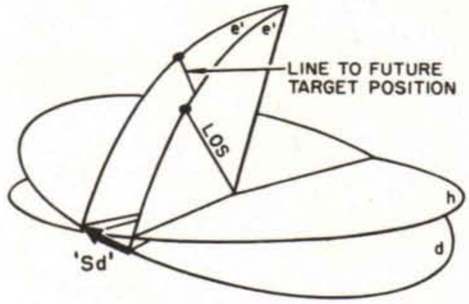
Deck Angular Movement

The angle between the normal plane through the line of sight, and the vertical plane through the line to the future target position, measured in the deck plane from the normal plane through the line of sight.

'Sd'

Deck Angular Movement

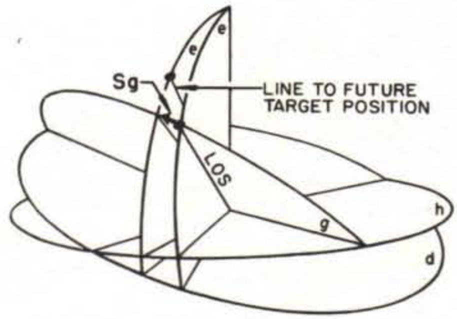
The angle between the normal plane through the line of sight, and the normal plane through the line to the future target position, measured in the deck plane from the normal plane through the line of sight.



Sg

Traverse Relative Angular Movement

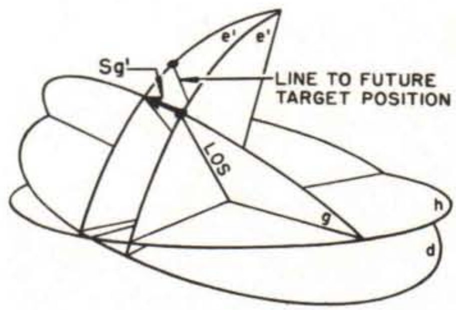
Angle between the line of sight, and the vertical plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the horizontal plane.



Sg'

Traverse Relative Angular Movement

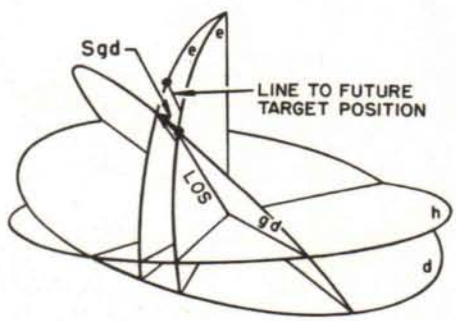
Angle between the line of sight, and the normal plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the horizontal plane.



Sgd

Traverse Relative Angular Movement

Angle between the line of sight, and the vertical plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the deck plane.



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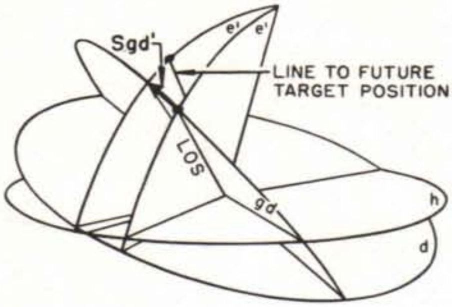
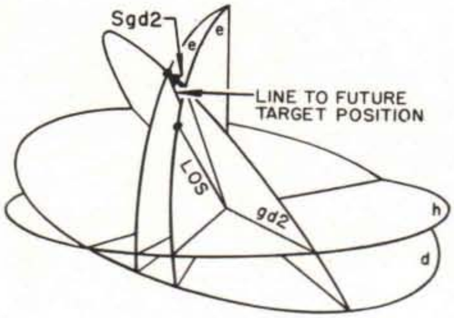
Sgd'



Traverse Relative Angular Movement

Angle between the line of sight, and the normal plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the gun elevation axis in the deck plane.

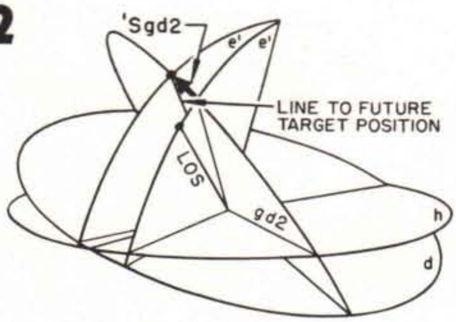
Sgd2



Traverse Relative Angular Movement

Angle between the line to the future target position, and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the deck plane.

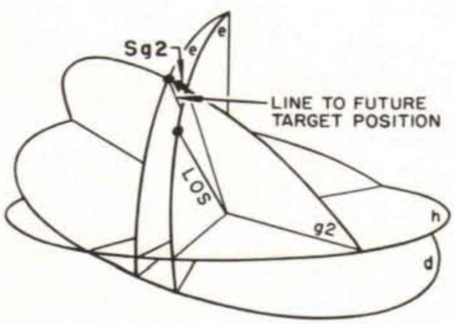
'Sgd2



Traverse Relative Angular Movement

Angle between the line to the future target position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the deck plane.

Sg2



Traverse Relative Angular Movement

Angle between the line to the future target position, and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the horizontal plane.

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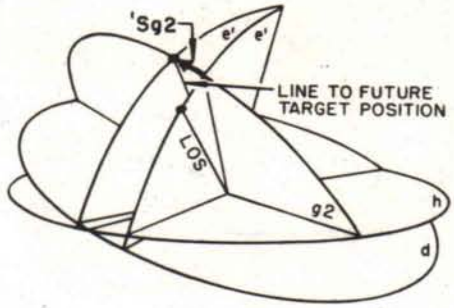
'Sg2

Traverse Relative Angular Movement

Angle between the line to the future target position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the gun elevation axis in the horizontal plane.

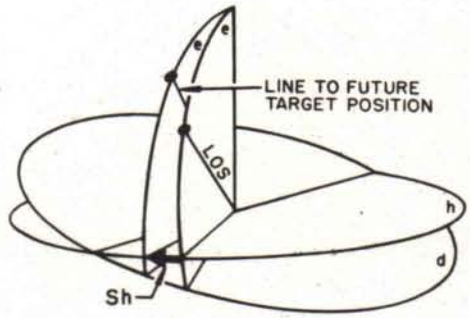


Sh

Horizontal Angular Movement

Angle between the vertical plane through the line of sight, and the vertical plane through the line to the future target position, measured in the horizontal plane from the vertical plane through the line of sight.

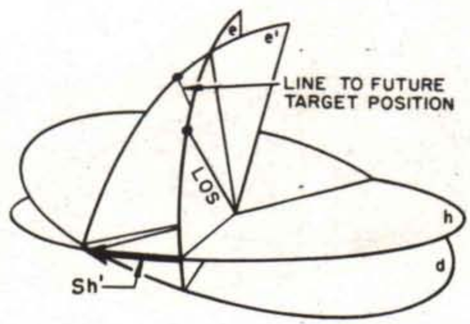
Note: 1. Previously used for Horizontal Target Speed. See ***Mht***



Sh'

Horizontal Angular Movement

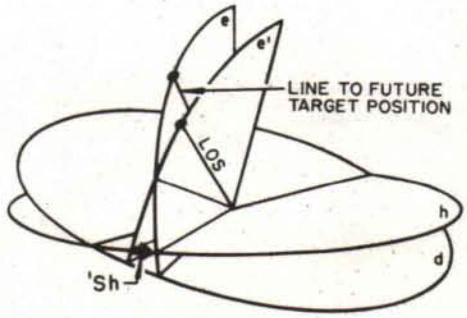
Angle between the vertical plane through the line of sight, and the normal plane through the line to the future target position, measured in the horizontal plane from the vertical plane through the line of sight.



'Sh

Horizontal Angular Movement

Angle between the normal plane through the line of sight, and the vertical plane through the line to the future target position, measured in the horizontal plane from the normal plane through the line of sight.



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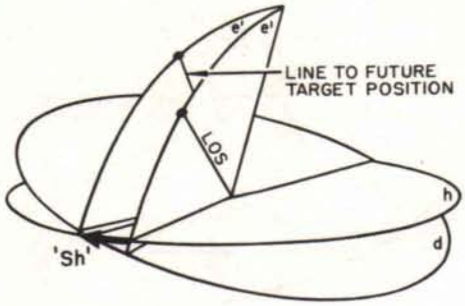
'Sh'



Horizontal Angular Movement

Angle between the normal plane through the line of sight, and the normal plane through the line to the future target position, measured in the horizontal plane from the normal plane through the line of sight.

So

Own Ship Speed

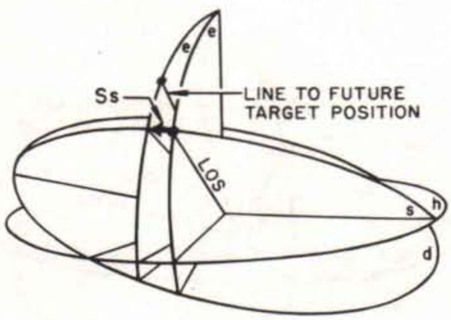
See ***Mho***

Sr

Relative Target Speed

See ***M***

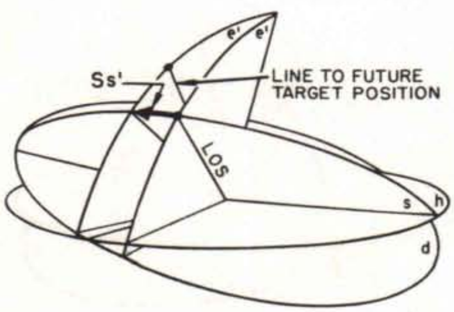
Ss



Traverse Relative Angular Movement

Angle between the line of sight, and the vertical plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane.

Ss'



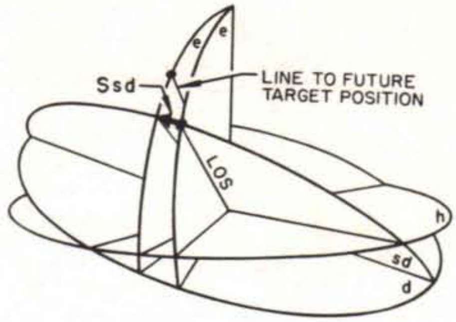
Traverse Relative Angular Movement

Angle between the line of sight, and the normal plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane.

Ssd

Traverse Relative Angular Movement

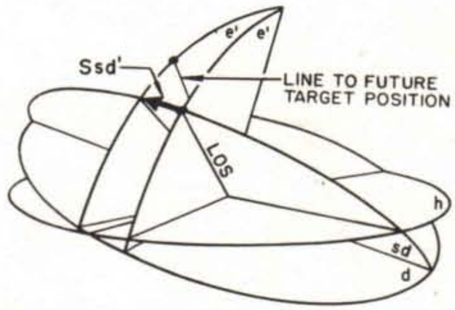
Angle between the line of sight, and the vertical plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the deck plane.



Ssd'

Traverse Relative Angular Movement

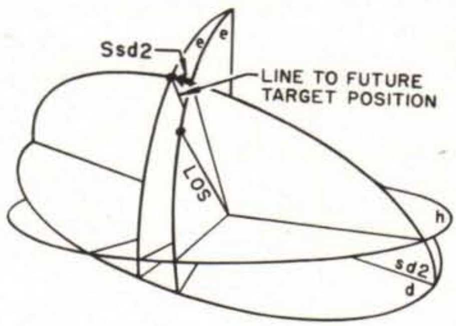
Angle between the line of sight, and the normal plane through the line to the future target position, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the deck plane.



Ssd2

Traverse Relative Angular Movement

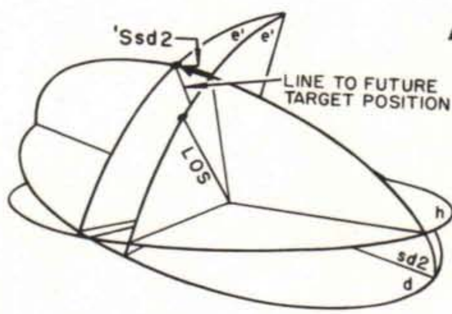
Angle between the line to the future target position, and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the deck plane.



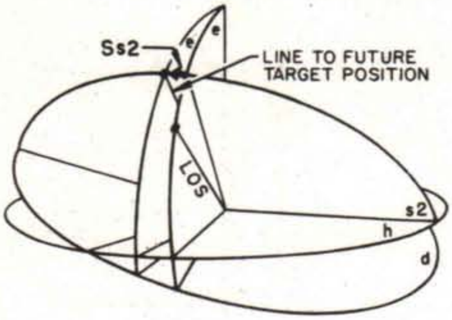
'Ssd2

Traverse Relative Angular Movement

Angle between the line to the future target position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the deck plane.



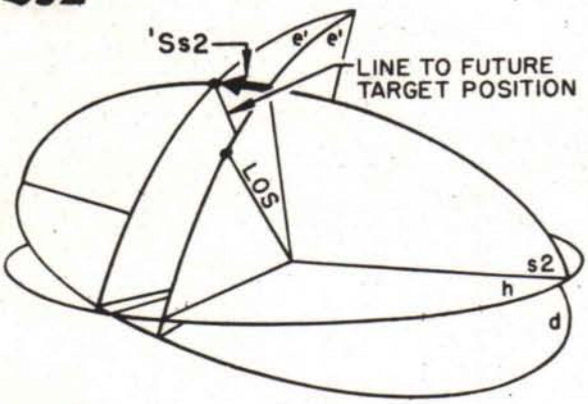
Ss2



Traverse Relative Angular Movement

Angle between the line to the future target position, and the vertical plane through the line of sight, measured from the vertical plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the horizontal plane.

'Ss2



Traverse Relative Angular Movement

Angle between the line to the future target position, and the normal plane through the line of sight, measured from the normal plane through the line of sight in the slant plane through the line to the future target position and through the director elevation axis in the horizontal plane.

Sw

True Wind Speed

See ***Wh***

Swr

Apparent Wind Speed

See ***Wha***

Time **T**

Clock time.

Time of Flight **Tf**

See *T2*

Present Time of Flight **Tfo**

See *T1*

Dead Time **Tg**

The time between setting the fuze and the firing of the projectile.

Present Time of Flight **T1**

The time of flight of the projectile to the present target position.

Note: 1. Previously called *Tfo*

Time of Flight **T2**

The time of flight of the projectile to the future target position.

Note: 1. Previously called *Tf*

Fuze Setting Order **T5**

Fuze setting in seconds.

U

Initial Velocity

The velocity of the projectile with respect to the gun muzzle at the instant the projectile leaves the gun. This velocity is independent of the reference frame used for measurement.

U1

Average Velocity to Present Target Position

The average velocity of the projectile to the present target position referred to the frame used by the fire control system. This velocity multiplied by present time of flight equals present range, $U1 \times T1 = R$.

U2

Average Velocity to Future Target Position

The average velocity of the projectile to the future target position referred to the frame used by the fire control system. This velocity multiplied by time of flight equals future range, $U2 \times T2 = R2$.

e(U)

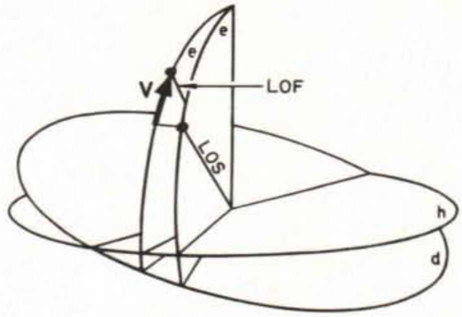
Loss of Initial Velocity

V

Sight Angle

The difference in elevation between the line of sight and the line of fire, measured in a vertical plane.

Note: 1. Previously called *VV*

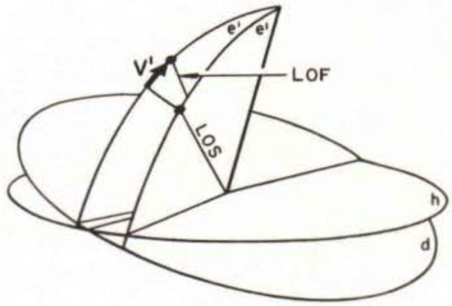


V′

Sight Angle

The difference in elevation between the line of sight and the line of fire, measured in a normal plane.

Note: 1. Previously called *V′d*



V′d

Sight Angle

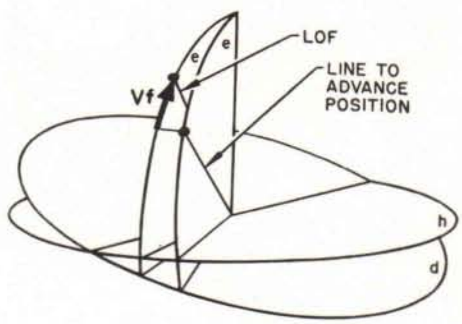
See ***V′***

Vf

Superelevation

The angle by which the gun must be elevated above the advance position to account for curvature of the trajectory, measured in the vertical plane through the line of fire.

Note: 1. Now symbolized by enclosing the applicable sight angle in parentheses and preceding by modifier ***b***. For example, ***b***(***Vs***)

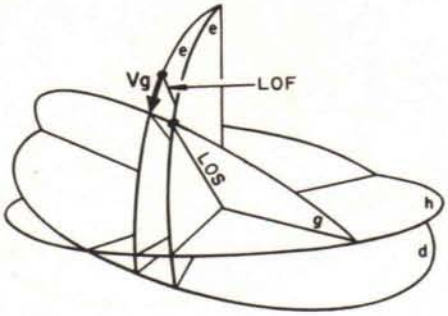


Vfm

Correction to sight angle to account for changes in initial velocity.

Note: 1. Now symbolized by enclosing applicable sight angle in parentheses and preceding by modifier ***u***. For example, ***u***(***Vs***)

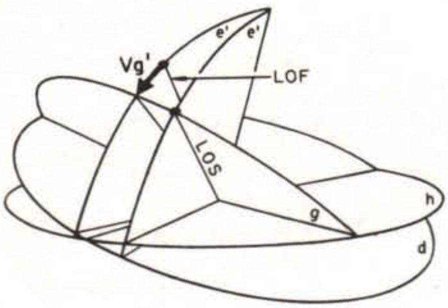
Vg



Sight Angle

The angle between the line of fire, and the slant plane through the line of sight and through the gun elevation axis in the horizontal plane, measured from the line of fire in the vertical plane through the line of fire.

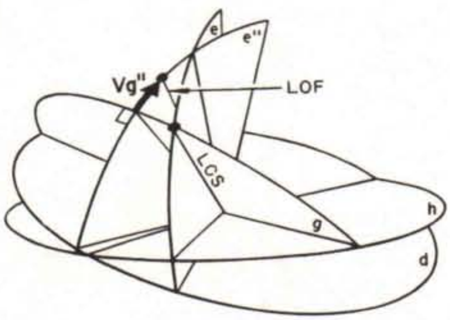
Vg'



Sight Angle

The angle between the line of fire, and the slant plane through the line of sight and through the gun elevation axis in the horizontal plane, measured from the line of fire in the normal plane through the line of fire.

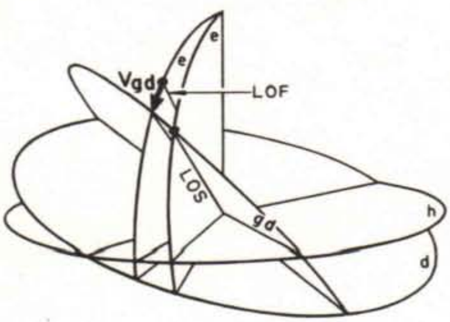
Vg''



Sight Angle

Angle between the line of fire, and the slant plane through the line of sight and through the gun elevation axis in the horizontal plane, measured to the line of fire in the plane through the line of fire perpendicular to the slant plane.

Vgd



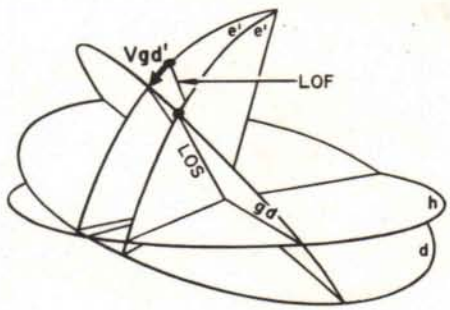
Sight Angle

Angle between the line of fire, and the slant plane through the line of sight and through the gun elevation axis in the deck plane, measured from the line of fire in the vertical plane through the line of fire.

Vgd'

Sight Angle

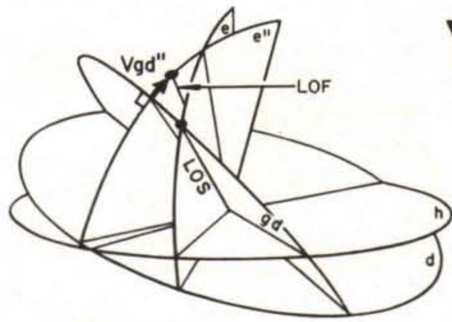
Angle between the line of fire, and the slant plane through the line of sight and through the gun elevation axis in the deck plane, measured from the line of fire in the normal plane through the line of fire.



Vgd''

Sight Angle

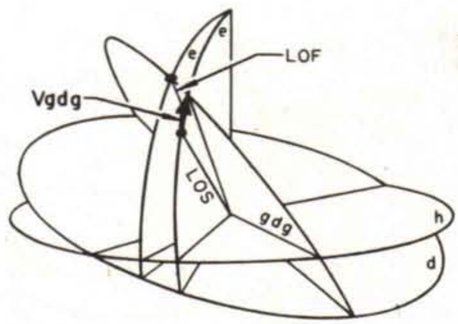
Angle between the line of fire, and the slant plane through the line of sight and through the gun elevation axis in the deck plane, measured to the line of fire in the plane through the line of fire perpendicular to the slant plane.



Vgdg

Sight Angle

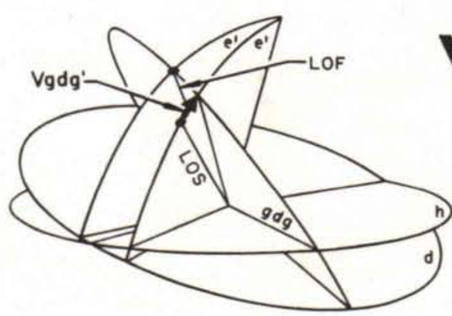
Angle between the line of sight, and the slant plane through the line of fire and through the gun elevation axis in the deck plane, measured from the line of sight in the vertical plane through the line of sight.



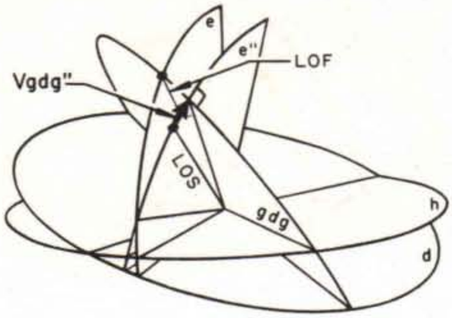
Vgdg'

Sight Angle

Angle between the line of sight, and the slant plane through the line of fire and through the gun elevation axis in the deck plane, measured from the line of sight in the normal plane through the line of sight.



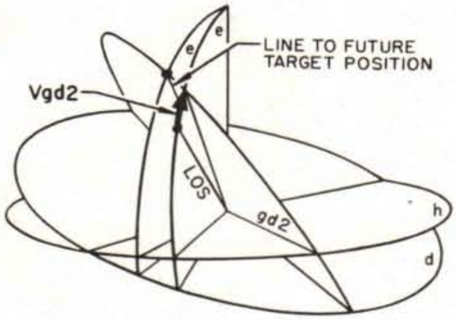
Vgdg''



Sight Angle

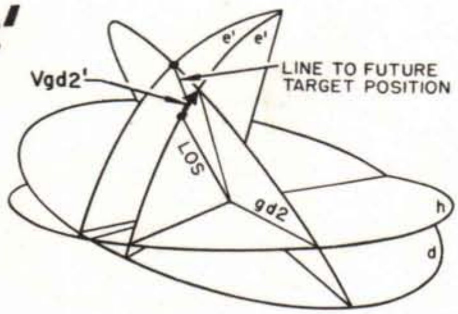
Angle between the line of sight, and the slant plane through the line of fire and through the gun elevation axis in the deck plane, measured from the line of sight in the plane through the line of sight perpendicular to the slant plane.

Vgd2



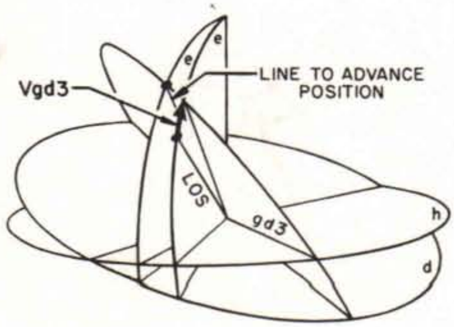
Angle between the line of sight, and the slant plane through the line to the future target position and through the gun elevation axis in the deck plane, measured from the line of sight in the vertical plane through the line of sight.

Vgd2'



Angle between the line of sight, and the slant plane through the line to the future target position and through the gun elevation axis in the deck plane, measured from the line of sight in the normal plane through the line of sight.

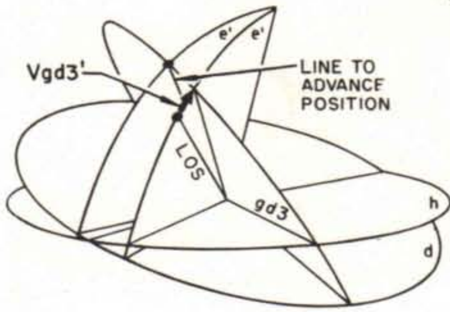
Vgd3



Angle between the line of sight, and the slant plane through the line to the advance position and through the gun elevation axis in the deck plane, measured from the line of sight in the vertical plane through the line of sight.

V_{gd3}'

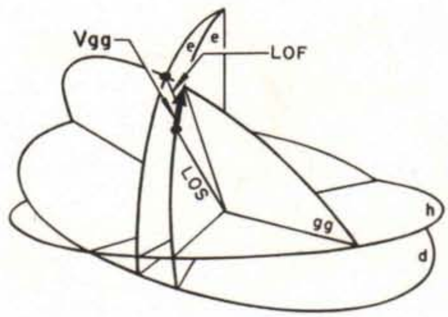
Angle between the line of sight, and the slant plane through the line to the advance position and through the gun elevation axis in the deck plane, measured from the line of sight in the normal plane through the line of sight.



V_{gg}

Sight Angle

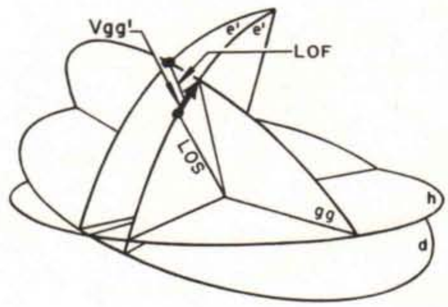
Angle between the line of sight, and the slant plane through the line of fire and through the gun elevation axis in the horizontal plane, measured from the line of sight in the vertical plane through the line of sight.



V_{gg}'

Sight Angle

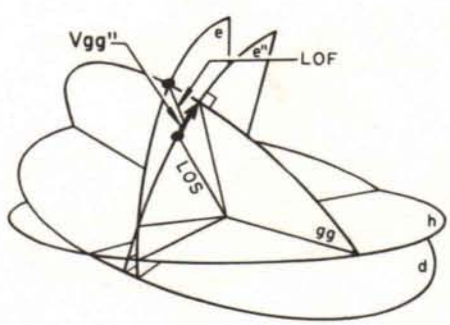
Angle between the line of sight, and the slant plane through the line of fire and through the gun elevation axis in the horizontal plane, measured from the line of sight in the normal plane through the line of sight.



V_{gg}''

Sight Angle

Angle between the line of sight, and the slant plane through the line of fire and through the gun elevation axis in the horizontal plane, measured from the line of sight in the plane through the line of sight perpendicular to the slant plane.



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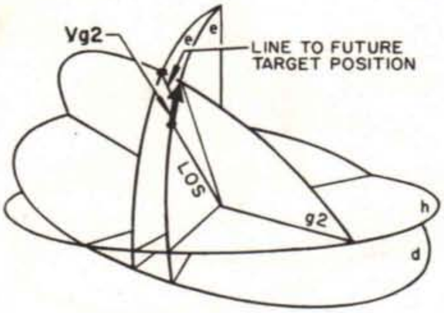
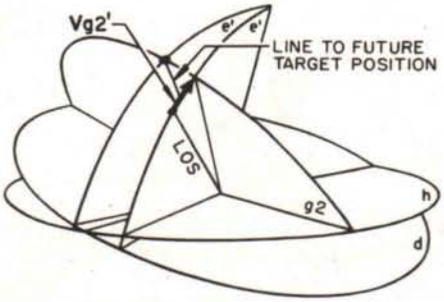
Vg2



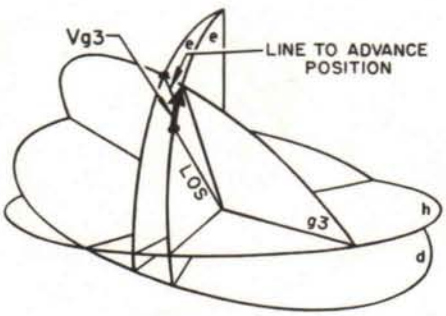
Angle between the line of sight, and the slant plane through the line to the future target position, and through the gun elevation axis in the horizontal plane, measured from the line of sight in the vertical plane through the line of sight.

Vg2′



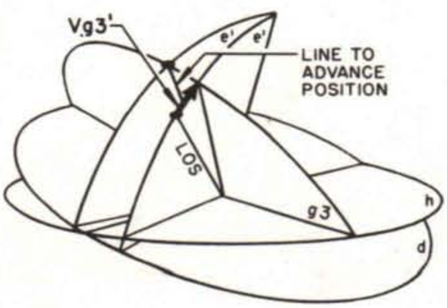
Angle between the line of sight, and the slant plane through the line to the future target position, and through the gun elevation axis in the horizontal plane, measured from the line of sight in the normal plane through the line of sight.

Vg3



Angle between the line of sight, and the slant plane through the line to the advance position, and through the gun elevation axis in the horizontal plane, measured from the line of sight in the vertical plane through the line of sight.

Vg3′

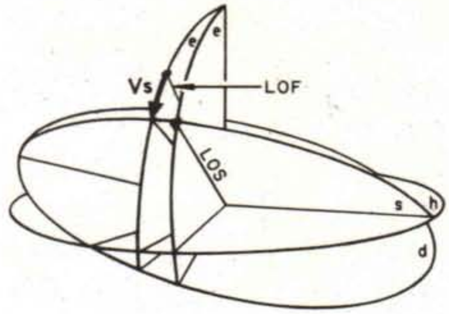


Angle between the line of sight, and the slant plane through the line to the advance position and through the gun elevation axis in the horizontal plane, measured from the line of sight in the normal plane through the line of sight.

Vs

Sight Angle

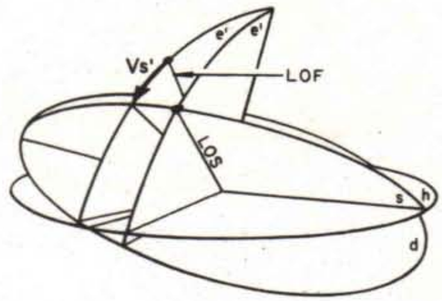
Angle between the line of fire, and the slant plane through the line of sight and through the director elevation axis in the horizontal plane, measured from the line of fire in the vertical plane through the line of fire.



Vs'

Sight Angle

Angle between the line of fire, and the slant plane through the line of sight and through the director elevation axis in the horizontal plane, measured from the line of fire in the normal plane through the line of fire.



V's

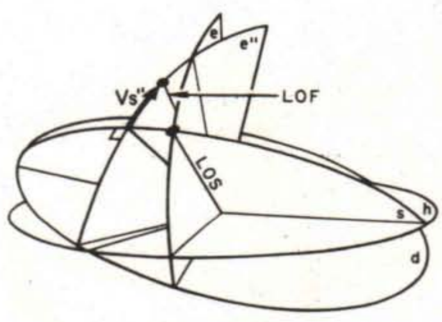
Sight Angle

See *Vsdg'*

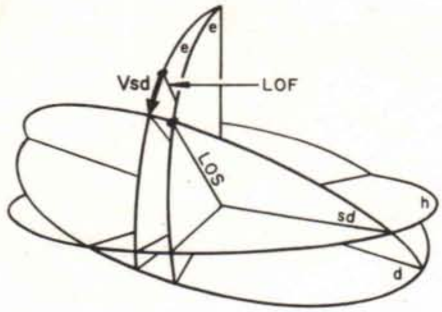
Vs''

Sight Angle

Angle between the line of fire, and the slant plane through the line of sight and through the director elevation axis in the horizontal plane, measured to the line of fire in the plane through the line of fire perpendicular to the slant plane.



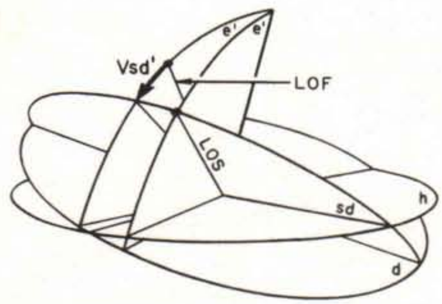
Vsd



Sight Angle

Angle between the line of fire, and the slant plane through the line of sight and through the director elevation axis in the deck plane, measured from the line of fire in the vertical plane through the line of fire.

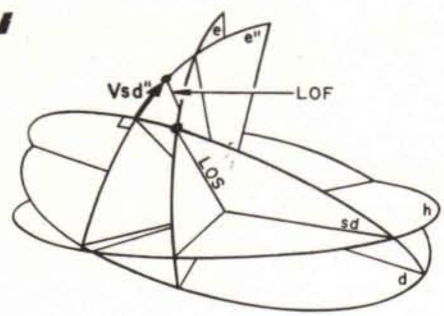
Vsd'



Sight Angle

Angle between the line of fire, and the slant plane through the line of sight and through the director elevation axis in the deck plane, measured from the line of fire in the normal plane through the line of fire.

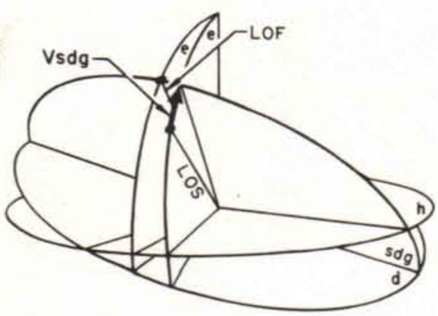
Vsd''



Sight Angle

Angle between the line of fire, and the slant plane through the line of sight and through the director elevation axis in the deck plane, measured to the line of fire in the plane through the line of fire perpendicular to the slant plane.

Vsdg



Sight Angle

Angle between the line of sight, and the slant plane through the line of fire and through the director elevation axis in the deck plane, measured from the line of sight in the vertical plane through the line of sight.

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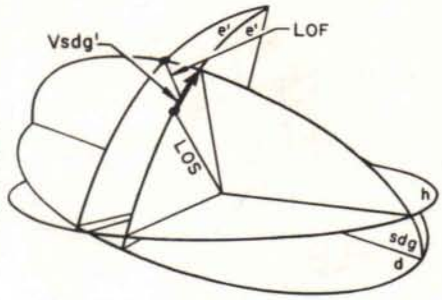
Vsdg′

Sight Angle

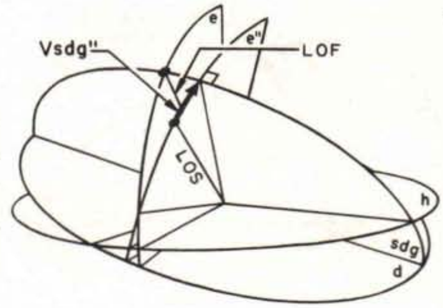
Angle between the line of sight, and the slant plane through the line of fire and through the director elevation axis in the deck plane, measured from the line of sight in the normal plane through the line of sight.



Vsdg″

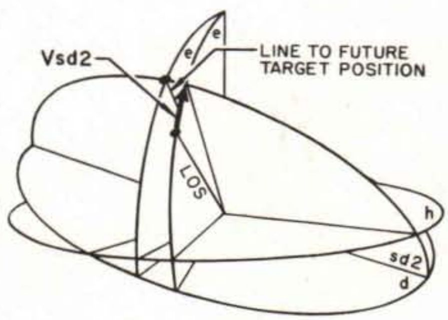
Sight Angle

Angle between the line of sight, and the slant plane through the line of fire and through the director elevation axis in the deck plane, measured from the line of sight in the plane through the line of sight perpendicular to the slant plane.



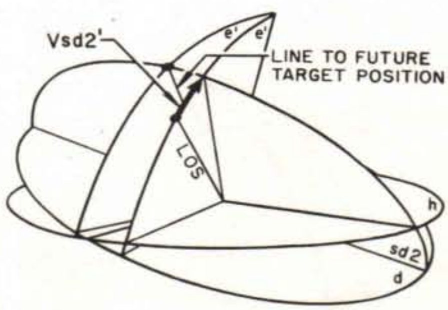
Vsd2

Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the deck plane, measured from the line of sight in the vertical plane through the line of sight.

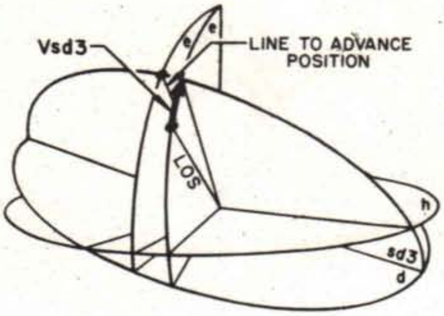


Vsd2′

Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the deck plane, measured from the line of sight in the normal plane through the line of sight.

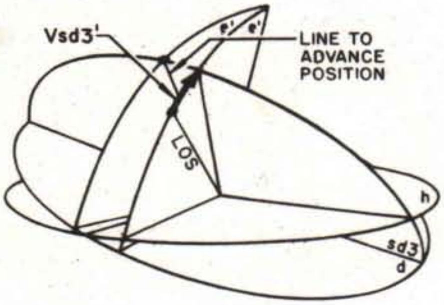


Vsd3



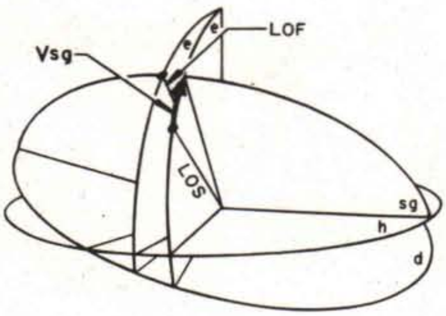
Angle between the line of sight, and the slant plane through the line to the advance position and through the director elevation axis in the deck plane, measured from the line of sight in the vertical plane through the line of sight.

Vsd3′



Angle between the line of sight, and the slant plane through the line to the advance position and through the director elevation axis in the deck plane, measured from the line of sight in the normal plane through the line of sight.

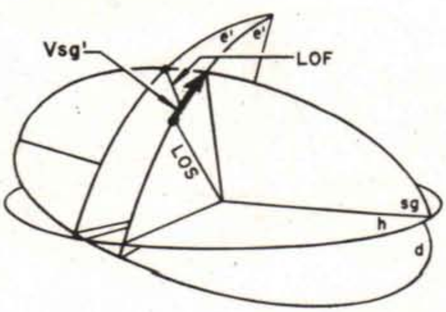
Vsg



Sight Angle

Angle between the line of sight, and the slant plane through the line of fire and through the director elevation axis in the horizontal plane, measured from the line of sight in the vertical plane through the line of sight.

Vsg′



Sight Angle

Angle between the line of sight, and the slant plane through the line of fire and through the director elevation axis in the horizontal plane, measured from the line of sight in the normal plane through the line of sight.

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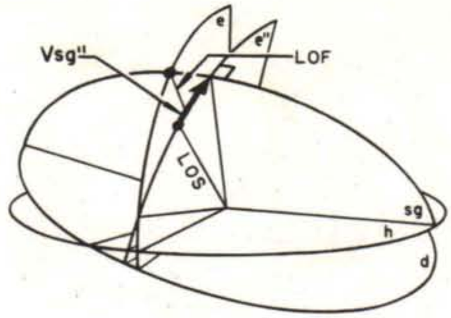
Vsg''

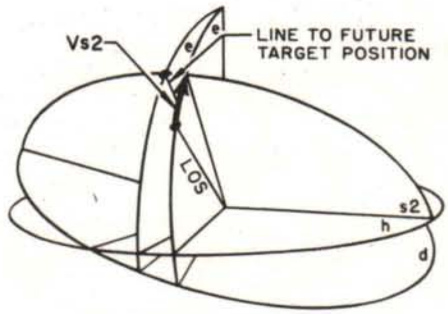
Sight Angle

Angle between the line of sight, and the slant plane through the line of fire and through the director elevation axis in the horizontal plane, measured from the line of sight in the plane through the line of sight perpendicular to the slant plane.



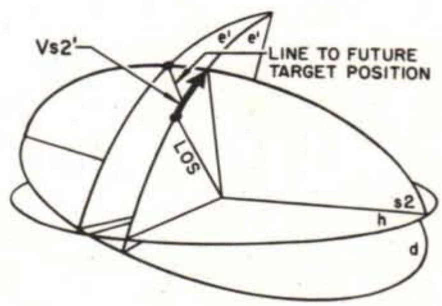
Vs2

Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the horizontal plane, measured from the line of sight in the vertical plane through the line of sight.



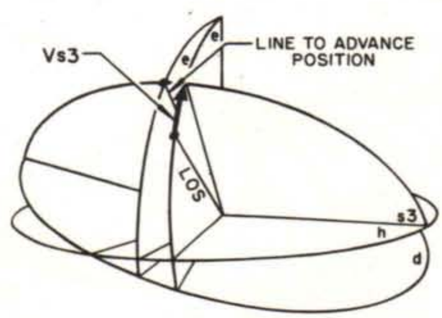
Vs2'

Angle between the line of sight, and the slant plane through the line to the future target position and through the director elevation axis in the horizontal plane, measured from the line of sight in the normal plane through the line of sight.



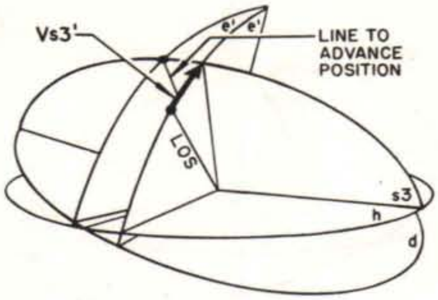
Vs3

Angle between the line of sight, and the slant plane through the line to the advance position and through the director elevation axis in the horizontal plane, measured from the line of sight in the vertical plane through the line of sight.



891927 O—

Vs3'



Angle between the line of sight, and the slant plane through the line to the advance position and through the director elevation axis in the horizontal plane, measured from the line of sight in the normal plane through the line of sight.

Vt

The part of sight angle accounting for relative movement between own ship and target.

Note: 1. Now symbolized by enclosing the applicable sight angle in parentheses and preceding by modifier ***m***. For example, ***m*(*Vs*)**

Vw

The part of sight angle accounting for the effect of wind on the projectile during the time of flight.

Note: 1. Now symbolized by enclosing the applicable sight angle in parentheses and preceding by modifier ***w***. For example, ***w*(*Vs*)**

Vx

Complementary Error Correction

The part of sight angle accounting for the effect of deflection prediction on gun elevation.

Note: 1. Now symbolized by enclosing the applicable sight angle in parentheses and preceding by modifier ***j***. For example, ***j*(*Vs*)**

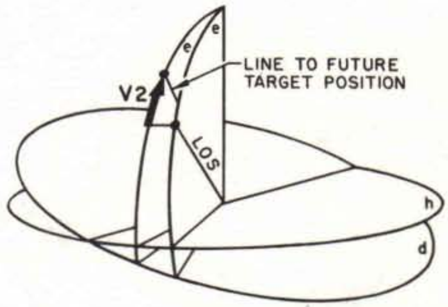
Trunnion Tilt Correction

Vz

The part of gun elevation order accounting for the tilting of the gun trunnions due to cross-level.

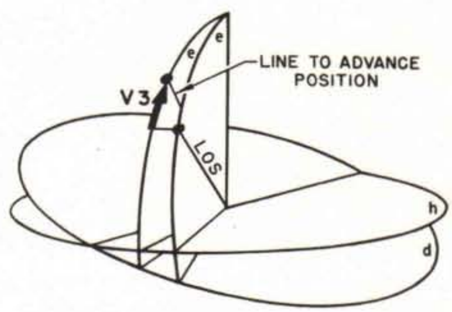
V2

The difference in elevation between the present and future target positions measured in a vertical plane.



V3

The difference in elevation between the present target position and the advance position measured in a vertical plane.



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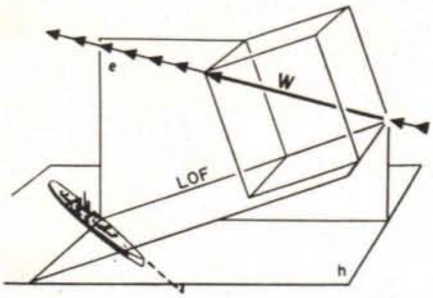
W



True Wind Speed

The total rate of the true wind measured with respect to the earth.

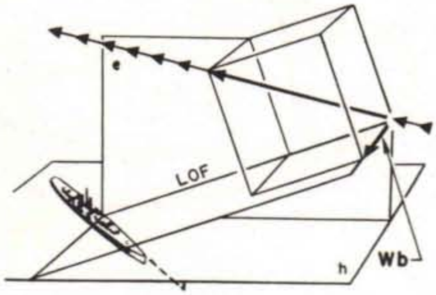
Note: 1. To express the total rate of apparent wind, modifier ***a*** is added, and symbol is ***Wa***
2. To express the total rate of own ship wind, modifier ***o*** is added, and symbol is ***Wo***

Wa

Apparent Wind Speed

See Note 1 under ***W***

Wb



The rate of the true wind in the horizontal plane perpendicular to the vertical plane through the line of fire, measured with respect to the earth.

Note: 1. Previously called *Xwg*
2. To express same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wba***
3. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wbo***
4. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wbs***

Wba

See Note 2 under ***Wb***

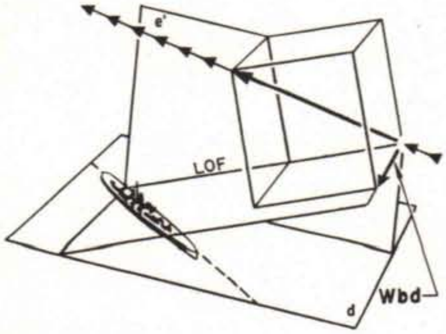
Note: 1. Previously called *WrD*
2. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wbas***

Wbas

See Note 2 under ***Wba***

Note: 1. Previously called *Xwr*

Wbd



The rate of the true wind in the deck plane perpendicular to the normal plane through the line of fire, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wbda***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wbdo***
3. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wbds***

Wbda

See Note 1 under ***Wbd***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wbdas***

Wbdas

See Note 1 under ***Wbda***

Wbdo

See Note 2 under ***Wbd***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wbdos***

Wbdos

See Note 1 under ***Wbdo***

Wbds

See Note 3 under ***Wbd***

Wbo

See Note 3 under ***Wb***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wbos***

Wbos

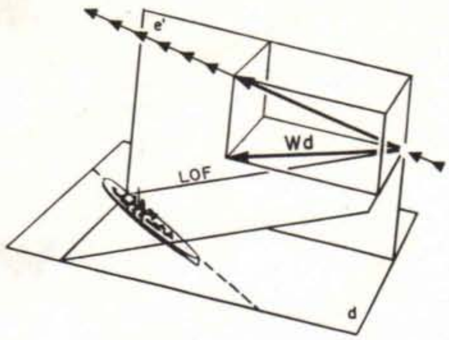
See Note 1 under ***Wbo***

Wbs

See Note 4 under ***Wb***

Note: 1. Previously called *Xw*

Wd



The rate of the true wind in the deck plane and in the normal plane through the total true wind speed vector, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wda***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wdo***

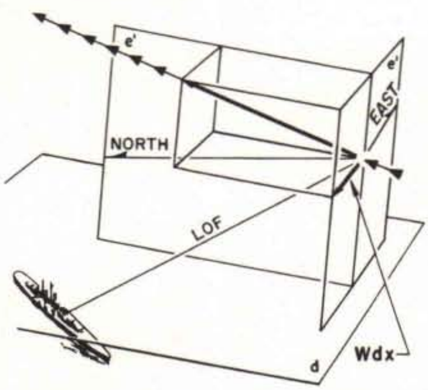
Wda

See Note 1 under ***Wd***

Wdo

See Note 2 under ***Wd***

Wdx



The rate of the true wind in the deck plane and in the East-West normal plane, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wdxa***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wdxo***

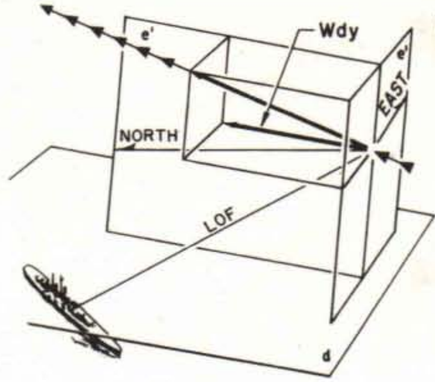
Wdxa

See Note 1 under ***Wdx***

Wdxo

See Note 2 under ***Wdx***

Wdy



The rate of the true wind in the deck plane and in the North-South normal plane, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier *a* is added, and symbol is ***Wdya***
2. To express the same rate of own ship wind, modifier *o* is added, and symbol is ***Wdyo***

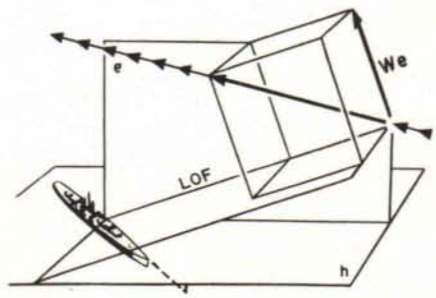
Wdya

See Note 1 under ***Wdy***

Wdyo

See Note 2 under ***Wdy***

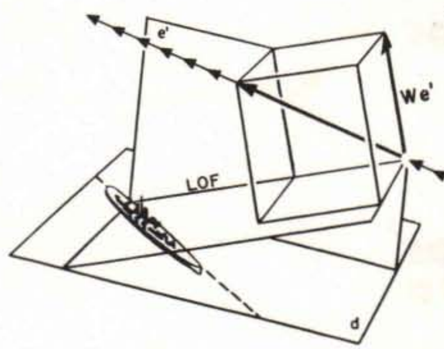
We



The rate of the true wind perpendicular to the line of fire in the vertical plane through the line of fire, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier *a* is added, and symbol is ***Wea***
2. To express the same rate of own ship wind, modifier *o* is added, and symbol is ***Weo***
3. To express the same rate with respect to LOS, modifier *s* is added, and symbol is ***Wes***

We'



The rate of the true wind perpendicular to the line of fire in the normal plane through the line of fire, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier *a* is added, and symbol is ***Wea'***
2. To express the same rate of own ship wind, modifier *o* is added, and symbol is ***Weo'***
3. To express the same rate with respect to the LOS, modifier *s* is added, and symbol is ***Wes'***

Wea

See Note 1 under ***We***

Note: 1. To express the same rate with respect to LOS, modifier *a* is added, and symbol is ***Weas***
2. Previously called *WrE*

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Wea′

See Note 1 under ***We′***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Weas′***

Weas

See Note 1 under ***Wea***

Weas′

See Note 1 under ***Wea′***

Weo

See Note 2 under ***We***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Weos***

Weo′

See Note 2 under ***We′***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Weos′***

Weos

See Note 1 under ***Weo***

Weos′

See Note 1 under ***Weo′***

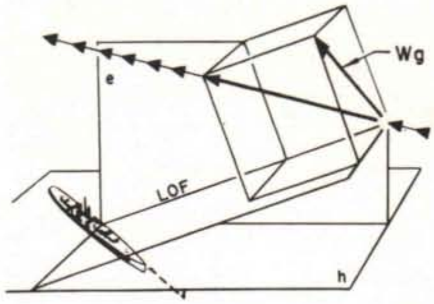
Wes

See Note 3 under ***We***

Wes′

See Note 3 under *We′*

Wg



The total rate of the true wind perpendicular to the line of fire, measured with respect to the earth.

Note: 1. To express the same component of apparent wind, modifier ***a*** is added, and symbol is ***Wga***
2. To express the same component of own ship wind, modifier ***o*** is added, and symbol is ***Wgo***

Wga

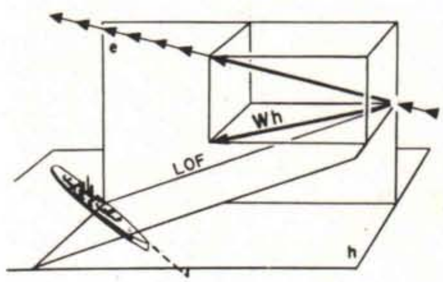
See Note 1 under *Wg*

Wgo

See Note 2 under *Wg*

Wh

Horizontal True Wind Speed



The rate of the true wind in the horizontal plane and in the vertical plane through the total true wind speed vector, measured with respect to the earth.

Note: 1. To express the same rate of the apparent wind, modifier ***a*** is added, and symbol is ***Wha***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Who***
3. Previously called *Sw*

Wha

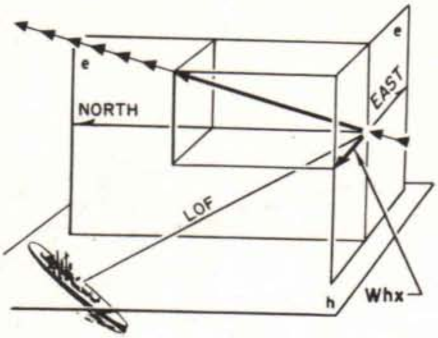
See Note 1 under *Wh*

Note: 1. Previously called *Swr*

Who

See Note 2 under *Wh*

Whx



The rate of the true wind in the horizontal plane and in the East-West vertical plane, measured with respect to the earth.

Note: 1. To express the same rate of the apparent wind, modifier ***a*** is added, and symbol is ***Whxa***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Whxo***

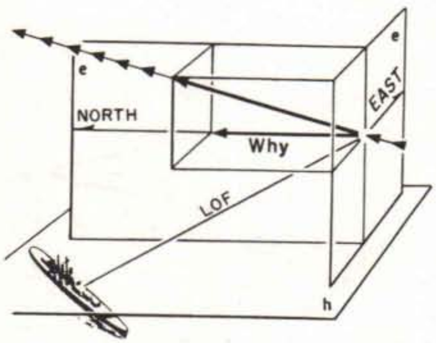
Whxa

See Note 1 under ***Whx***

Whxo

See Note 2 under ***Whx***

Why



The rate of the true wind in the horizontal plane and in the North-South vertical plane, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Whya***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Whyo***

Whya

See Note 1 under ***Why***

Whyo

See Note 2 under ***Why***

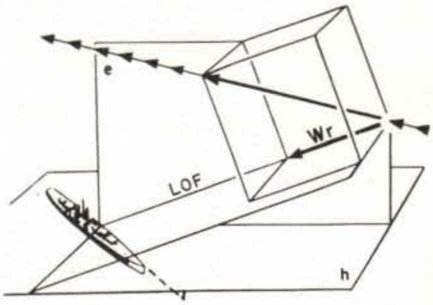
Wo

See Note 2 under ***W***

Wr

The rate of the true wind along the line of fire, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wra***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wro***
3. To express the same rate with respect to the LOS, modifier ***s*** is added, and symbol is ***Wrs***



Wra

See Note 1 under ***Wr***

Note: 1. Previously called ***WrR***
2. To express the same rate with respect to the LOS, modifier ***s*** is added, and symbol is ***Wras***

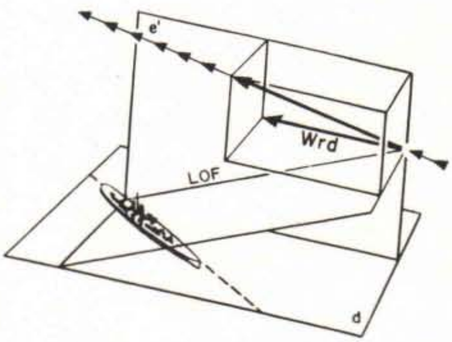
Wras

See Note 2 under ***Wra***

Wrd

The rate of the true wind in the deck plane and in the normal plane through the line of fire, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wrda***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wrdo***
3. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wrds***



WrD

See ***Wba***

Wrda

See Note 1 under ***Wrd***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wrdas***

Wrdas

See Note 1 under ***Wrda***

Wrdo

See Note 2 under ***Wrd***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wrdos***

Wrdos

See Note 2 under ***Wrdo***

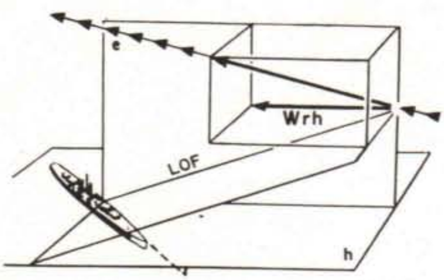
Wrds

See Note 3 under ***Wrd***

WrE

See ***Wea***

Wrh



The rate of the true wind in the horizontal plane and in the vertical plane through the line of fire measured with respect to the earth.

Note: 1. Previously called *Ywg*
2. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wrha***
3. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wrho***
4. To express the same rate with respect to LOS, modifier ***s*** is added and symbol is ***Wrhs***

Wrha

See Note 2 under ***Wrh***

Note: 1. Previously called *Ywgr*

2. To express the same rate with respect to LOS, modifier ***s*** is added and symbol is ***Wrhas***

Wrhas

See Note 2 under ***Wrha***

Note: 1. Previously called *Ywr*

Wrho

See Note 3 under ***Wrh***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added and symbol is ***Wrhos***

Wrhos

See Note 1 under ***Wrho***

Wrhs

See Note 4 under ***Wrh***

Note: 1. Previously called *Yw*

Wro

See Note 2 under ***Wr***

Note: 1. To express the same rate with respect to LOS, modifier ***s*** is added, and symbol is ***Wros***

Wros

See Note 1 under ***Wro***

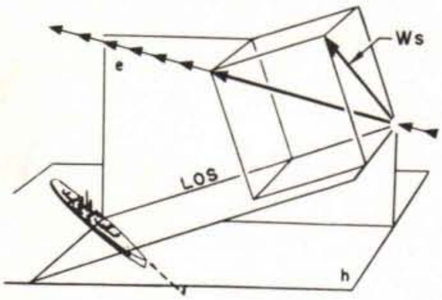
WrR

See ***Wra***

Wrs

See Note 3 under ***Wr***

Ws



The total rate of the true wind perpendicular to the line of sight, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added and symbol is ***Wsa***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wso***

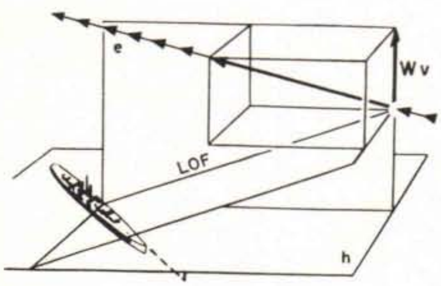
Wsa

See Note 1 under ***Ws***

Wso

See Note 2 under ***Ws***

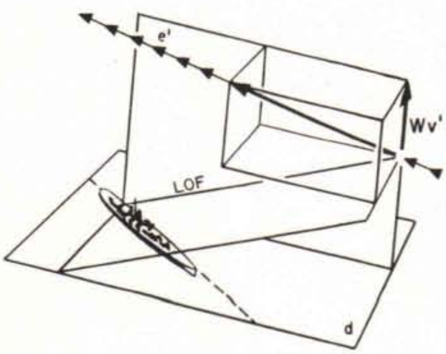
Wv



Vertical rate of the true wind in the vertical plane through the line of fire, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wva***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wvo***

Wv'



Normal rate of the true wind in the normal plane through the line of fire measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wva'***
2. To express the same rate of own ship wind modifier ***o*** is added, and symbol is ***Wvo'***

Wva

See Note 1 under ***Wv***

Wva′

See Note 1 under ***Wv′***

Wvo

See Note 2 under ***Wv***

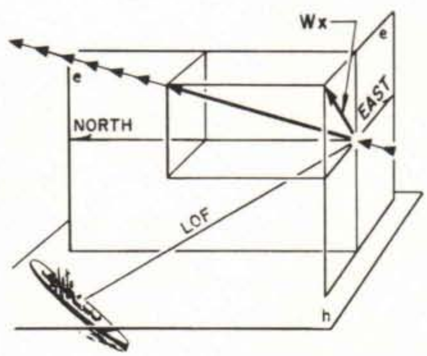
Wvo′

See Note 2 under ***Wv′***

Wx

The rate of the true wind in the East-West vertical plane, measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added and symbol is ***Wxa***
2. To express the same rate of own ship wind, modifier ***o*** is added, and symbol is ***Wxo***



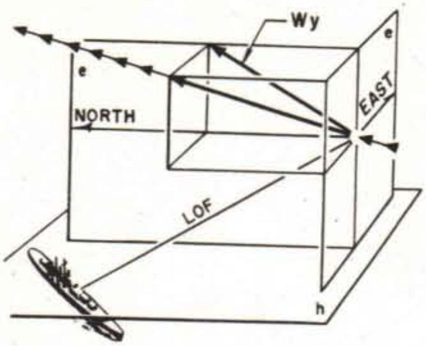
Wxa

See Note 1 under ***Wx***

Wxo

See Note 2 under ***Wx***

Wy



The rate of the true wind in the North-South vertical plane measured with respect to the earth.

Note: 1. To express the same rate of apparent wind, modifier ***a*** is added, and symbol is ***Wya***
2. To express the same rate of own ship wind modifier ***o*** is added, and symbol is ***Wyo***

Wya

See Note 1 under ***Wy***

Wyo

See Note 2 under ***Wy***

See ***Mbo*** — X_o

See ***Mbt*** — X_t

See ***Wbs*** — X_w

See ***Wb*** — X_{wg}

See ***Wbas*** — X_{wr}

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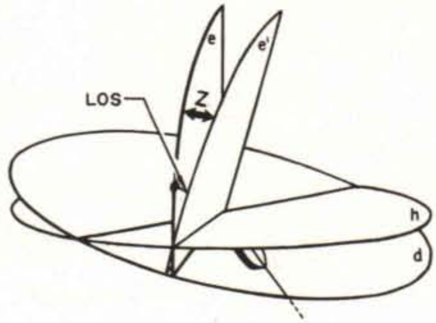
Y_o	See ***Mrho***
Y_t	See ***Mrht***
Y_w	See ***Wrhs***
Y_{wg}	See ***Wrh***
Y_{wgr}	See ***Wrha***
Y_{wr}	See ***Wrhas***

Z

Cross Level

Angle between the vertical plane through the line of sight, and the normal plane through the intersection of the vertical plane through the line of sight and the horizontal plane, measured about the axis which is the intersection of the vertical plane through the line of sight and the horizontal plane. Positive direction is clockwise when viewed along axis inward from target.

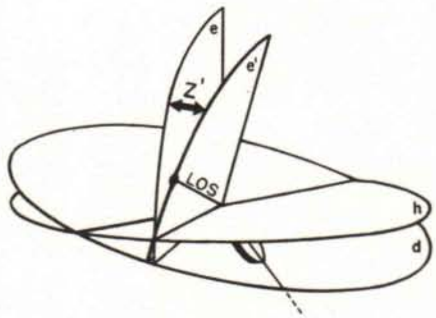


Note: 1. Previously called *Zh*

Z′

Cross Level

Angle between the normal plane through the line of sight, and the vertical plane through the intersection of the normal plane through the line of sight and the horizontal plane, measured about the axis which is the intersection of the normal plane through the line of sight and the horizontal plane. Positive direction is clockwise when viewed along axis inward from target.



Note: 1. Previously called *Z′h*

Zh

Cross Level

See ***Z***

Z′h

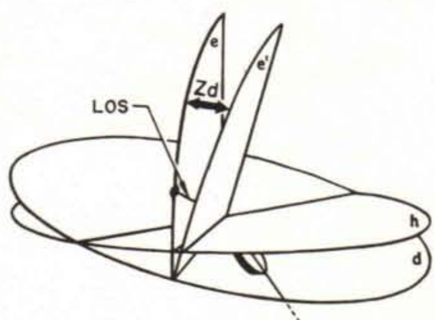
Cross Level

See ***Z′***

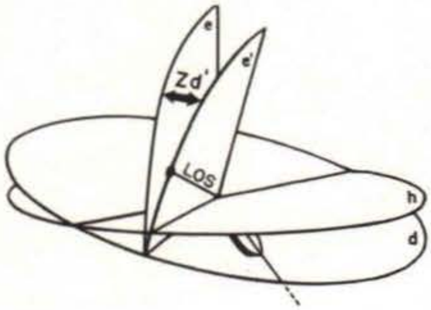
Zd

Cross Level

Angle between the vertical plane through the line of sight, and the normal plane through the intersection of the vertical plane through the line of sight and the deck plane, measured about the axis which is the intersection of the vertical plane through the line of sight and the deck plane. Positive direction is clockwise when viewed along axis inward from target.



Zd′



Cross Level

Angle between the normal plane through the line of sight, and the vertical plane through the intersection of the normal plane through the line of sight and the deck plane, measured about the axis which is the intersection of the normal plane through the line of sight and the deck plane. Positive direction is clockwise when viewed along axis inward from target.

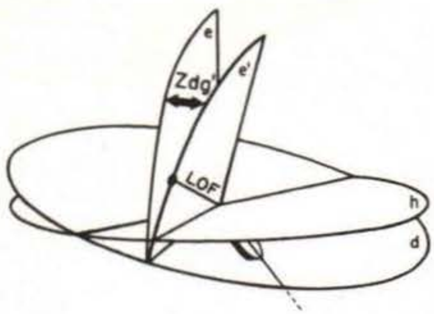
Note: 1. Previously called *Z′d*

Z′d

Cross Level

See ***Zd′***

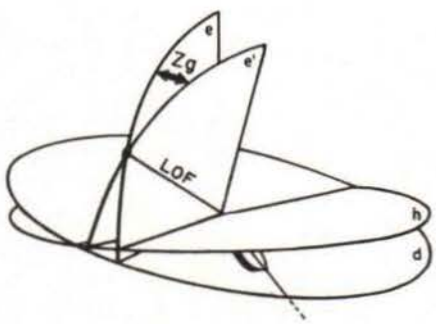
Zdg′



Trunnion Tilt Angle

Angle between the normal plane through the line of fire, and the vertical plane through the intersection of the normal plane through the line of fire and the deck plane, measured about the axis which is the intersection of the normal plane through the line of fire and the deck plane. Positive direction is clockwise when viewed along axis inward from target.

Zg



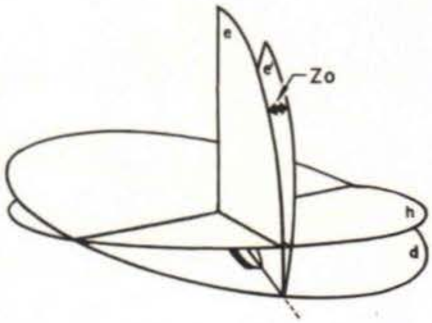
Angle between the vertical plane through the line of fire and the normal plane through the line of fire, measured about the line of fire as the axis. Positive direction is clockwise when viewed along axis inward from target.

Zo

Roll

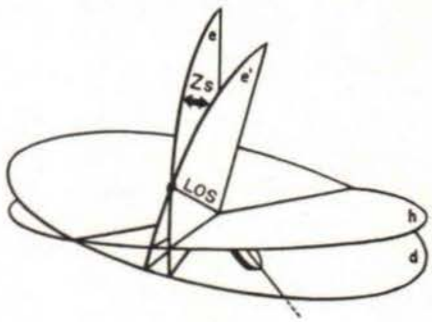
Angle between the vertical plane through own ship centerline, and the normal plane through the intersection of the vertical plane through own ship centerline and the deck plane, measured about the axis which is the intersection of the vertical plane through own ship centerline and the deck plane. Positive direction is clockwise when viewed inward from own ship bow.

Note: 1. Previously called *M*



Zs

Angle between the vertical plane through the line of sight and the normal plane through the line of sight, measured about the line of sight as the axis. Positive direction is clockwise when viewed along axis inward from target.



Z′s

See ***Zs***

APPENDIX A

BASIC SYMBOLS

Symbol	Name	Meaning when used alone
A	Angular movement in elevation.	The difference in elevation from the horizontal plane between the present line of sight and the line to the future target position, measured upward to the line to the future target position in a vertical plane.
B	Bearing	The relative bearing of the target measured from the vertical plane through own ship centerline to the vertical plane through the line of sight in the horizontal plane clockwise from own ship centerline.
C	Course	The course of the target from the north-south vertical plane to the vertical plane through the relative target speed vector in the frame used by the fire control system, measured in the horizontal plane clockwise from north.
D	Rate of	The differentiating operator d/dt.
E	Elevation	The elevation of the target above the horizontal plane measured upward from the horizontal plane in the vertical plane through the line of sight.
Ei	Level	The angle between the horizontal plane and the deck plane, measured downward from the horizontal plane (on the target side of own ship) in the vertical plane through the line of sight.
F		
G		
H		
I	Angle of inclination	Only useful as a rate. *DI* expresses the rate of rotation of own ship with respect to the earth frame.
J	Jump deviation	No meaning.
K		
L	Sight deflection	The total lead angle between the line of sight and the line of fire.

Symbol	Name	Meaning when used alone
M	Linear movement	The total linear displacement of the target during the time of flight due to relative motion between own ship and target in the frame used by the fire control system.
N		
O		
P	Gun parallax base length.	The total linear displacement between the reference point and the gun measured along the gun parallax base line.
Ps	Director parallax base length.	The total linear displacement between the reference point and the director measured along the director parallax base line.
Q		
R	Range	The distance between own ship and target measured along the line of sight.
S	Lateral angular movement.	The total angular displacement measured from the line of sight to the line to the future target position.
T	Time	Elapsed time.
U	Velocity	The initial velocity of the projectile with respect to the gun muzzles at the instant the projectile leaves the gun.
V	Sight angle	The difference in elevation between the line of sight and the line of fire measured in a vertical plane.
W	Wind rate	The total rate of the true wind measured with respect to the earth.
X		
Y		
Z	Cross level	Angle between the vertical plane through the line of sight, and the normal plane through the intersection of the vertical plane through the line of sight and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the line of sight and the horizontal plane.

APPENDIX B

BASIC SYMBOL MODIFIERS

Modifier	Name	Used to indicate
a	Apparent	Quantities expressing rates and angles of apparent wind.
b	Bearing	Quantities in direction affecting bearing.
c		
d	Deck	Quantities measured in, from, or about axes in the deck.
e	Elevation	Quantities in direction affecting elevation.
f		
g	Gun	Quantities measured from, to, or about line of fire or gun.
h	Horizontal	Quantities measured in horizontal plane.
i		
i		
k	Earth	Quantities expressing earth rates.
l		
m		
n		
o	Own ship	Quantities measured from, to, or about own ship centerline, and quantities expressing own ship rates and own ship wind rates.
p	Prediction	
q	Heading	The compass head of own ship or target.
r	Range	Quantities in direction affecting range.
$\overline{rs}$	Roll stabilized	Quantities measured in, from or to the roll stabilized plane.

Modifier	Name	Used to indicate
s	Line of sight	Quantities measured from, to, or about line of sight or director.
t	Target	Quantities measured from, to, or about target centerline, and quantities expressing target rates.
u		
v	Vertical	Quantities in vertical direction.
w	Wind	Quantities related to wind.
x	East-west	Quantities measured in east-west direction.
y	North-south	Quantities measured from north or in north-south direction.
z	Cross level	Quantities related to cross roll.
'	Prime (before quantity).	Measurement from a normal plane.
'	Prime (after quantity).	Measurement to or in a normal plane.
"	Double prime (before quantity).	Measurement from a plane normal to the slant plane.
"	Double prime (after quantity).	Measurement to or in a plane normal to the slant plane.
1	Present position	Quantities measured with respect to present target position.
2	Future position	Quantities measured with respect to future target position.
3	Advance position	Quantities measured with respect to advance position.
4	Aiming position	Quantities measured with respect to aiming position.
5	Fuze	Quantities used in fuze computations.

APPENDIX C

QUANTITY MODIFIERS

These modifiers are used before or after parentheses

Modifier	Name	Before the parentheses	After the parentheses
a	Advance	The portion of the quantity measured to the advance position.	No meaning.
b	Ballistics	The portion of the quantity accounting for superelevation or drift.	The quantity corrected for the effect of superelevation or drift.
c	Computed or generated.	The value of a quantity as computed or generated in the mechanism.	No meaning.
d	Designated	The designated value of the quantity.	No meaning.
e	Estimated or error.	The estimated value of the quantity or the error in that quantity (error meaning used only with initial velocity).	No meaning.
f	Function	A function of the quantity	No meaning.
g	Dead time	The correction to the quantity due to dead time.	The quantity corrected for the effect of dead time.
h			
i	Increment	An increment of the quantity	No meaning.
j	Computational addition or partial.	A computational addition to the quantity.	A partial value of the quantity.
k	Earth	No meaning	The quantity referred to the earth frame.
l	Initial	The initial value of the quantity.	No meaning.

Modifier	Name	Before the parentheses	After the parentheses
m	Relative motion	The portion of that quantity accounting for relative motion between own ship and target.	The quantity corrected for the effect of relative motion between own ship and target.
n			
o	Observed or measured.	The observed or measured value of the quantity.	Referred to a frame rigidly attached to own ship.
p	Gun parallax	The portion of the quantity accounting for gun parallax.	The quantity corrected for the effect of gun parallax.
ps	Director parallax	The portion of the quantity accounting for director parallax.	The quantity corrected for the effect of director parallax.
q	Corrective input or spot.	A corrective input or spot to the quantity.	No meaning.
r	Rate control	The rate control correction to a quantity.	The quantity including the rate control correction.
s	Selected	A selected value of the quantity	Referred to the inertial frame.
u	Initial velocity loss.	The portion of the quantity accounting for change in initial velocity.	The change corrected for change in initial velocity.
v			
w	Wind	The portion of the quantity accounting for the effect of the wind.	The quantity corrected for the effect of the wind.
x			
y			
z			

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APPENDIX D

LISTING OF RELATED QUANTITIES FOR ANTIAIRCRAFT FIRE CONTROL

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Salem 92

OP 1700

(VOLUME 2)

STANDARD FIRE CONTROL SYMBOLS

FOR

UNDERWATER RELATED QUANTITIES

DEPARTMENT OF THE NAVY
BUREAU OF ORDNANCE

6 DECEMBER 1957

DEPARTMENT OF THE NAVY
BUREAU OF ORDNANCE
WASHINGTON 25, D. C.

6 December 1957

ORDNANCE PAMPHLET 1700 (VOLUME 2)

STANDARD FIRE CONTROL SYMBOLS FOR UNDERWATER RELATED QUANTITIES

1. The Ordnance Pamphlet 1700 series establishes and standardizes fire control symbols used in describing fire control problems and their solutions for the control of guns, underwater weapons, and missiles. Volume 2 establishes fire control symbols applicable to the underwater fire control problem as solved by naval fire control systems.

2. This publication is intended for use by all personnel concerned with applications of underwater control symbols.

3. The OP 1700 series includes two other volumes:

   OP 1700 (Volume 1) Standard Fire Control Symbols

   OP 1700 (Volume 3) Standard Fire Control Symbols for Missile Related Quantities.

4. This publication must be used in conjunction with OP 1700 (Volume 1) "Standard Fire Control Symbols"; symbols described therein are common to both gun and underwater control, and are not repeated in this volume.

5. This publication, together with OP 1700 (Volumes 1 and 3) supersede NAVORD OD 3447, which shall be destroyed.

F. S. Withington

John Quinn

John Quinn
Rear Admiral, U. S. Navy
Deputy Chief, Bureau of Ordnance

Chapter 1

SYMBOL SYSTEM

Sonar Position Quantities

When sonar equipment is used to determine present target position, the sonar transducer is not pointed at the target because of curvature of the sound beam. Therefore, the required present target position quantities must be computed from available sonar measurements. The symbolization of these sonar measurement quantities and the corrections applied to them to obtain present target position require the expression of two additional positions, as illustrated in figure 1.

Apparent Position. The position of the target is indicated by the sonar transducer; that is, the position from which the sound beam appears to come. It differs from present target positions because of target travel during time of sound travel from target to own ship and refraction of the sound beam due to temperature, pressure, and salinity gradients.

Past Target Position. This is the position of the target from which the sound beam actually comes; that is, the position of the target when hit by the sound beam. It differs from present target position because of target travel during the time of sound travel from target to own ship, and it differs from apparent position because of refraction of the sound beam due to temperature, pressure, and salinity gradients.

The classes of quantities expressing the apparent and past target positions are the same as those used to express present target positions: bearings (***B***), elevations (***E***), level (***Ei***), ranges (***R***), and cross level (***Z***). These classes of quantities may be modified to refer to the line to the apparent target position by adding the modifier ***a***, or to refer to the line to the past target position by adding the modifier ***p***. These modifiers change the interpretation of the quantity to be referenced to the modified line rather than to the line of sight. Table 1 shows typical symbols using these modifiers.

Apparent Position. To express apparent position in the various coordinate systems, symbols for the same quantities used to express present target position are terminated by letter modifier ***a***. For example, for unstable spherical coordinates ***Bd′***, ***Ed′***, and ***R*** expressing present target position, the corresponding coordinates for apparent position are ***Bda′***, ***Eda′***, and ***Ra***.

Past Target Position. To express past target position in the various coordinate systems, symbols for the same quantities used to express present target position are terminated by letter modifier ***p***. For example, for stable cylindrical coordinates ***By***, ***Rh***, and ***Rv*** expressing present target position, the corresponding coordinates for past target position are ***Byp***, ***Rhp***, and ***Rvp***.

> NOTE: The modifier ***a*** refers to apparent target position in all cases except when used with symbols involving wind measurements; then it refers to apparent wind.

Navigational Parallax

When two or more ships operate as a unit to solve the underwater fire control problem, the distance between these ships is considered a parallax displacement. That is, in instances where one ship measures position data and transmits these data to another ship for use in computing a solution, a parallax correction is made for the displacement between the reference points of the two ships, as illustrated in figure 2.

The class of quantities expressing linear displacements between the computing-ship reference point and the assist-ship reference point is called "navigational parallax" and is represented by the basic symbol ***Pn***. The basic navigational parallax displacement quantity (symbolized ***Pn***) is the total linear distance between the computing-ship reference point and

Table 1—Typical Symbols Using Modifiers *a* and *p*

Present Target Position	Apparent Target Position	Past Target Position
B	*Ba*	*Bp*
B′	*Ba′*	*Bp′*
Bd	*Bda*	*Bdp*
Bd′	*Bda′*	*Bdp′*
Bdy	*Bdya*	*Bdyp*
Bdy′	*Bdya′*	*Bdyp′*
By	*Bya*	*Byp*
By′	*Bya′*	*Byp′*
E	*Ea*	*Ep*
E′	*Ea′*	*Ep′*
Ed	*Eda*	*Edp*
Ed′	*Eda′*	*Edp′*
Ei	*Eia*	*Eip*
Ei′	*Eia′*	*Eip′*
M	*Ma*	*Mp*
Mb	*Mba*	*Mbp*
Mbd	*Mbda*	*Mbdp*
Md	*Mda*	*Mdp*
Mdx	*Mdxa*	*Mdxp*
Mdy	*Mdya*	*Mdyp*
Me	*Mea*	*Mep*
Mh	*Mha*	*Mhp*
Mhx	*Mhxa*	*Mhxp*
Mhy	*Mhya*	*Mhyp*
Mr	*Mra*	*Mrp*
Mrd	*Mrda*	*Mrdp*
Mrh	*Mrha*	*Mrhp*
Ms	*Msa*	*Msp*
Mv	*Mva*	*Mvp*
Mv′	*Mva′*	*Mvp′*
Mx	*Mxa*	*Mxp*
My	*Mya*	*Myp*
R	*Ra*	*Rp*
Rd	*Rda*	*Rdp*
Rdx	*Rdxa*	*Rdxp*

Table 1—Typical Symbols Using Modifiers *a* and *p*—Continued

Present Target Position	Apparent Target Position	Past Target Position
Rdy	*Rdya*	*Rdyp*
Rh	*Rha*	*Rhp*
Rhx	*Rhxa*	*Rhxp*
Rhy	*Rhya*	*Rhyp*
Rv	*Rva*	*Rvp*
Rv′	*Rva′*	*Rvp′*
Rvd	*Rvda*	*Rvdp*
Rvd′	*Rvda′*	*Rvdp′*
Rx	*Rxa*	*Rxp*
Ry	*Rya*	*Ryp*
Z	*Za*	*Zp*
Z′	*Za′*	*Zp′*
Zd	*Zda*	*Zdp*
Zd′	*Zda′*	*Zdp′*
Zs	*Zsa*	*Zsp*

the assist-ship reference point measured along the navigational parallax base line.

Present Missile Position

Present missile position is symbolized in exactly the same manner as present target position, with the exception that a modifier is used. The two modifying letters used are ***m*** and ***j***. The definitions of these modifiers are as follows:

Symbol	Quantity	Definition
m	Missile centerline.	Quantities measured to, from, or about missile centerline.
j	Line to missile.	Quantities measured to, from, or about line from reference point to missile.

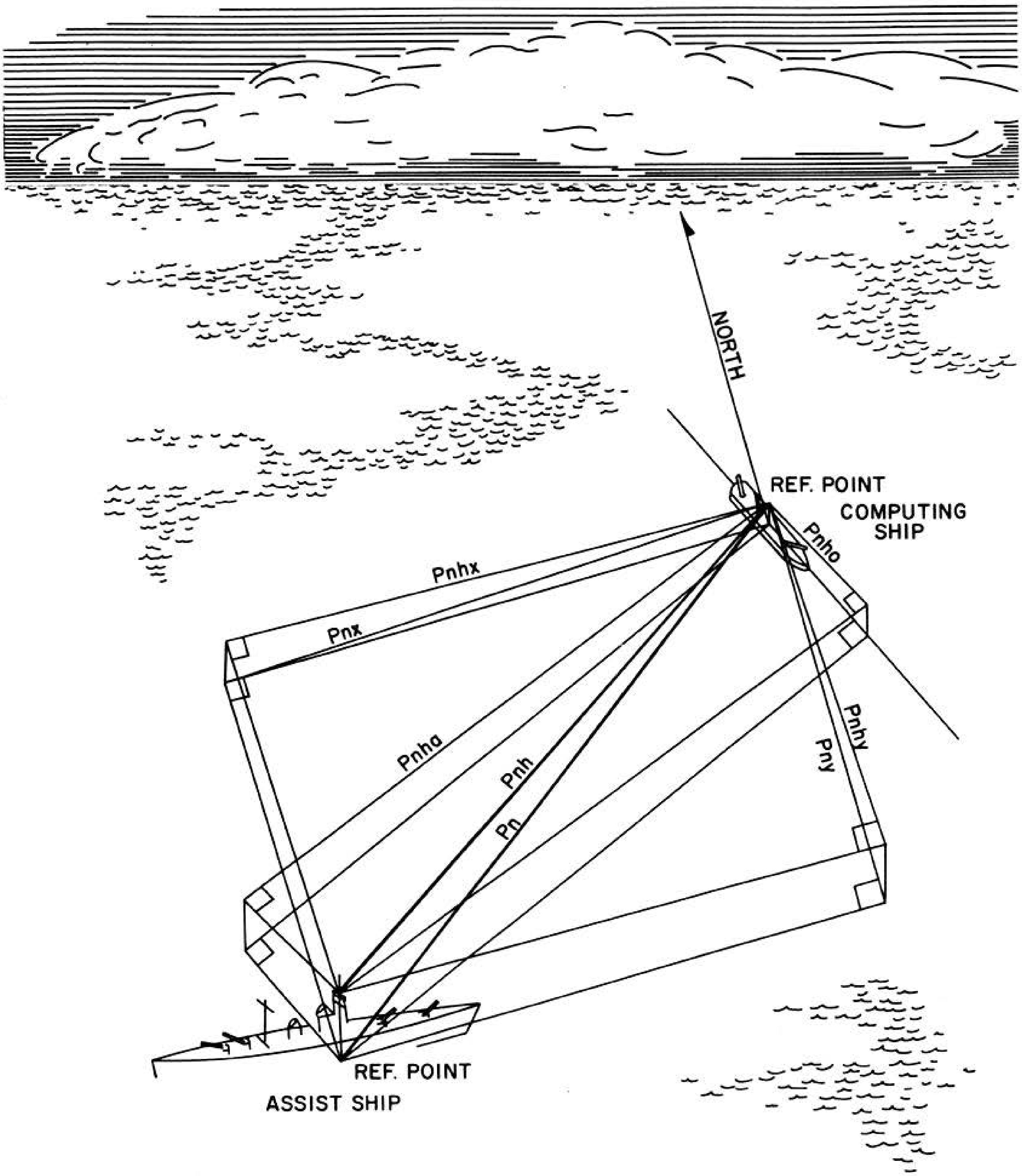


Figure 2—Navigational Parallax.

The modifying letter ***m*** when added to, or when replacing, the modifier ***t*** in a symbol defining present target position modifies that symbol to define missile centerline rather than target centerline.

The modifying letter ***j*** when added to, or when replacing, the modifier ***s*** in a symbol defining present target position modifies that symbol to define the line from the reference point to the missile rather than the line of sight. See table 2.

Table 2—Typical Equivalent Symbols

Present Target Position	Present Missile Position
Bd	***Bdj***
Bd′	***Bdj′***
Bdy	***Bdjy***
Bdy′	***Bdjy′***
No equivalent	***Bdm***
No equivalent	***Bdm′***
B	***Bj***
B′	***Bj′***
By	***Bjy***
By′	***Bjy′***
No equivalent	***Bm***
No equivalent	***Btm***

Gyro Angles

The class of quantities expressing angular offsets between the line of fire or the missile speed vector and the desired missile speed vector measured in the horizontal or deck planes is called "gyro angle" and is represented by the symbol ***G***.

The basic gyro-angle quantity (represented by ***G***) is the angle between the vertical plane through the line of fire and the vertical plane through the desired missile speed vector measured in the horizontal plane.

To express the same gyro angle measured in the deck plane, instead of the horizontal plane, Gyro angles ***G*** and ***Gd*** are further modified to indicate planes from (and to) which they are measured. To indicate the plane to which the offset is measured, the gyro angle symbol is followed by ***′*** (prime) for a plane normal to the deck plane; to indicate the plane from which the offset is measured, the gyro angle symbol is preceded by ***′*** (prime) for a plane normal to the deck plane. When no prime modifiers appear, the gyro angle is measured between vertical planes.

Missile Velocities

The class of quantities expressing missile velocities is represented by the basic symbol ***U***.

The basic missile-velocity quantity (represented by the basic symbol ***U***) is the initial velocity of the missile measured with respect to the gun or launcher at the instant the weapon leaves the gun or the launcher. This velocity is independent of the reference frame used for the measurement.

To express average missile velocity to a particular point in the trajectory of the missile, the basic symbol ***U*** is modified by adding the modifying number which describes that particular point.

> EXAMPLE. The average missile velocity to the future target position would be symbolized by ***U5*** if the future target position were defined by the number ***5*** in the weapon system being used.

To express average missile velocity between two particular points in the trajectory of the missile, the basic symbol is modified by adding the two numbers (separated with a dash) that describe the two positions.

> EXAMPLE. The average missile velocity from the water entry point to the future target position would be symbolized by ***U3–5*** if the water entry point were defined by the number ***3*** and the future target position by the number ***5*** in the weapon system being used.

Time

Time quantities are symbolized in exactly the same manner as missile velocity quantities with the exception that the basic symbol is ***T***

Radius of Turn

The class of quantities expressing the radius of turn is represented by the basic symbol ***Y***. This symbol is modified to describe whether the radius of turn is in reference to own ship, target, or the missile. These modifiers are ***o*** for own ship, ***t*** for target, and ***m*** for missile, making the symbols ***Yo***=radius of turn of own ship, ***Yt***=radius of turn of the target, and ***Ym***=radius of turn of the missile.

Distance

The class of quantities expressing distance is represented by the basic symbol ***H***. This symbol is modified to describe the particular distance desired. The distance may be linear or curvilinear, depending upon the definition of the symbol when modified. The class of quantities represented by the basic symbol ***H*** is similar to those represented by ***R*** (range) and ***P*** (parallax displacement), with the exception that symbols using ***H*** as the basic symbol require two modifiers to define the end points and the ***R*** and ***P*** symbols require only one modifier because they inherently define one end point.

Numbers

With the advent of many new weapon systems in the underwater ordnance field and the need for symbols describing the various positions and locations of the missile during its travel from own ship to target, it becomes increasingly complex to generate distinct symbols for every one of these quantities. Therefore, each weapon system will use numbers to define the locations of the missile during its travel. Refer to tables 3 through 6. Because the use of numbers is inherently restrictive, the numbers and their definitions will be unique to each weapon system (i. e., the definitions of the numbers used in the ASROC system will not necessarily be the same as those used in other systems). However, all weapon systems will use the numbers zero (***0***), one (***1***), and two (***2***) and the standard definition for each.

Symbol	Quantity	Definition
0	Will to fire	Quantities measured with respect to will or intent to fire or optimum time to fire.
1	Firing order	Quantities measured with respect to the physical action of firing i. e., closure of a firing key or any action which initiates an irretrievable firing sequence.
2	Fire	Quantities measured with respect to firing, i. e., ignition.

These numbers may or may not be used, depending upon the requirements of the system, but in no case will the definitions of these particular numbers vary in the underwater ordnance field.

In defining quantities involving the use of numbers, the construction of the symbol is the same as one that does not use numbers. The choice of the numbers and their application in a weapon system should be done with care, and thought should be given to the future requirements of the weapon system. Figure 3 and tables 3 and 4 illustrate how numbering of points is incorporated in a type of antisubmarine weapon system. Figure 4 and tables 5 and 6 illustrate the incorporation of numbers into a submarine weapon system. Numbers may be used to define points or lines wherever the standard use of letter modifiers is not applicable.

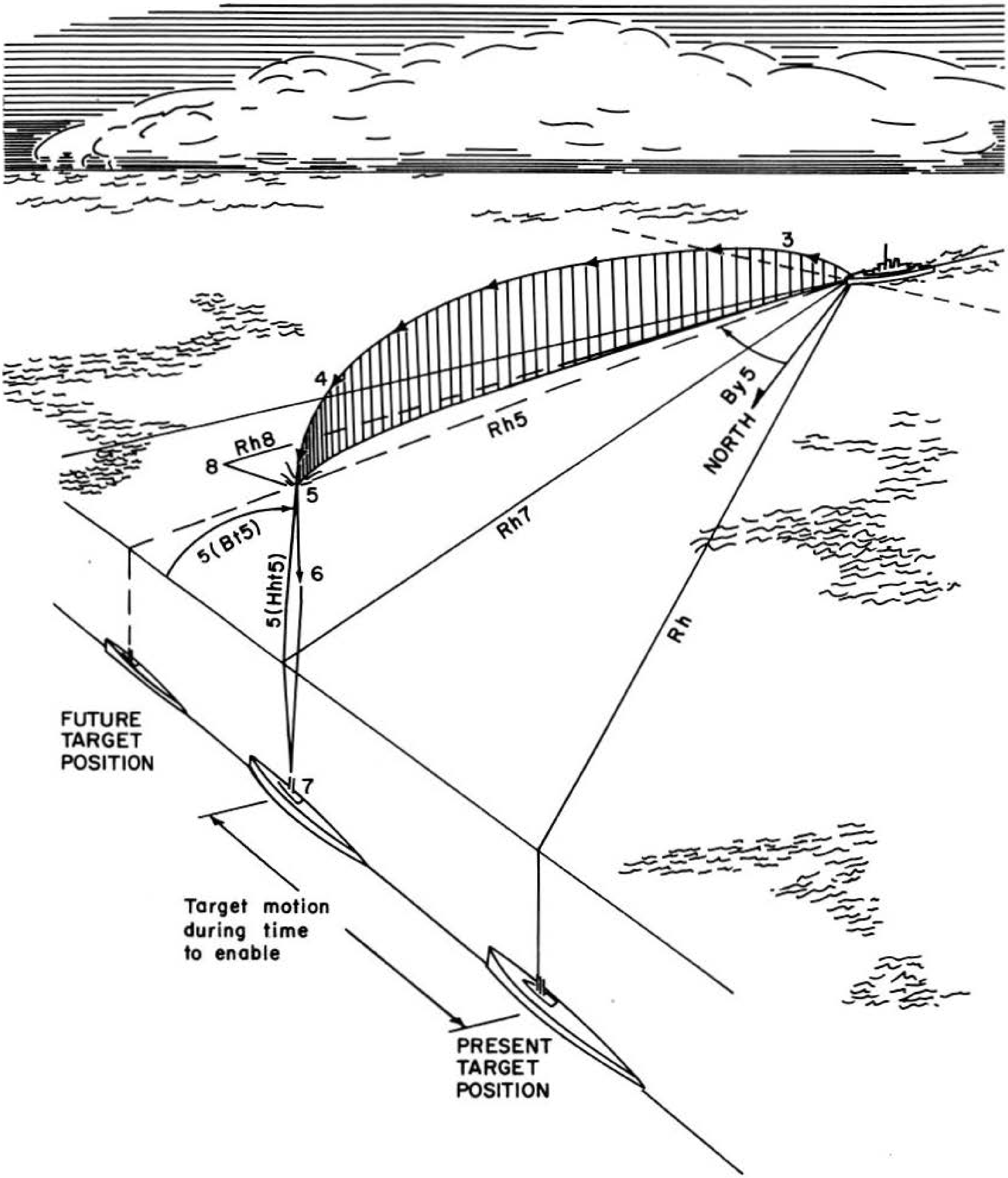


Figure 3—Use of Numbers in a Thrown Weapon System.

Table 3—Definitions of Numbers Used in a Thrown Weapon System

Symbol	Quantity	Definition
0	Will to fire	Quantities measured with respect to will or intent to fire or optimum time to fire.
1	Firing order	Quantities measured with respect to physical action of firing, i. e., closure of a firing key or any action which initiates an irretrievable firing sequence.
2	Fire	Quantities measured with respect to firing, i. e., ignition.
3	Thrust cut-off position	Quantities measured with respect to thrust cut-off position.
4	Separation position	Quantities measured with respect to separation position.
5	Water entry point	Quantities measured with respect to position where charge enters the water.
6	Enabling position	Quantities measured with respect to position where missile is enabled.
7	Future target position	Quantities measured with respect to future target position.
8	Aiming position	Quantities measured with respect to aiming position.

Table 4—Definitions of Terms Used in a Thrown Weapon System

Symbol	Quantity	Definition
s(Bt5)	Future target position	Angle between vertical plane through target speed vector and vertical plane containing desired missile water entry point and bow of target at future target position, measured in horizontal plane. Positive angles measured clockwise from bow of target.
By5	Water entry point bearing.	Angle between North-South vertical plane and vertical plane through line to computed water entry point, measured in horizontal plane. Positive angles measured clockwise from North.
s(Hht5)	Future target position offset.	Horizontal distance from future target position to desired missile water entry point.
Rh5	Effective range	Horizontal range from reference point to water entry point of charge at time of fire.
Rh8	Horizontal aiming range.	Horizontal range from own ship to target, combined with corrections and predictions necessary to compensate for own ship and target motion during time of flight, plus ballistic corrections and spots.
Rvu	Target depth	Depth of target below horizontal plane measured in vertical plane through line of sight.
c(Rvu)	Computed target depth	Computed depth of target below horizontal plane measured in vertical plane through line of sight.
T1–0	Dead time	Time from will to fire to instant of firing.
T0	Time of will to fire	The time of will or intent to fire or optimum time of fire.

Table 4—Definitions of Terms Used in a Thrown Weapon System—Continued

Symbol	Quantity	Definition
T1	Time of firing order	The time of the physical action of firing, i. e., closure of a firing key or any action which initiates an irretrievable firing sequence.
T2	Time of fire	The time of actual firing, i. e., ignition.
T3	Time to thrust cut-off	The time from instant of firing to instant of thrust cut-off.
T4	Time to separation	The time from instant of firing to instant of rocket and payload separation order.
T5	Time of water entry	The time from instant of firing to instant of water entry.
T6–5	Sinking time	Time from instant a charge strikes the water to time it is enabled.
T6	Enabling time	Time from instant of firing to instant charge is enabled.

Table 5—Definitions of Numbers Used in Submarine Firing of Torpedoes

Symbol	Quantity	Definition
0	Will to fire	Quantities measured with respect to will or intent to fire or optimum time to fire.
1	Firing order	Quantities measured with respect to physical action of firing, i. e., closure of a firing key or any action which initiates an irretrievable firing sequence.
2	Fire	Quantities measured with respect to firing, i. e., ignition.
3	Reach point	Quantities measured with respect to end of initial straight path of torpedo.
4	Gyro involute point	Quantities measured with respect to beginning of final torpedo track.
5	Present target position	Quantities measured with respect to present target position.
6	Future target position	Quantities measured with respect to future target position.
7	Advance point	Quantities measured with respect to intersection of a line parallel to final torpedo track passing through torpedo tube and a line perpendicular to final torpedo track passing through future target position.
8	Final torpedo track	Quantities measured with respect to final torpedo track.

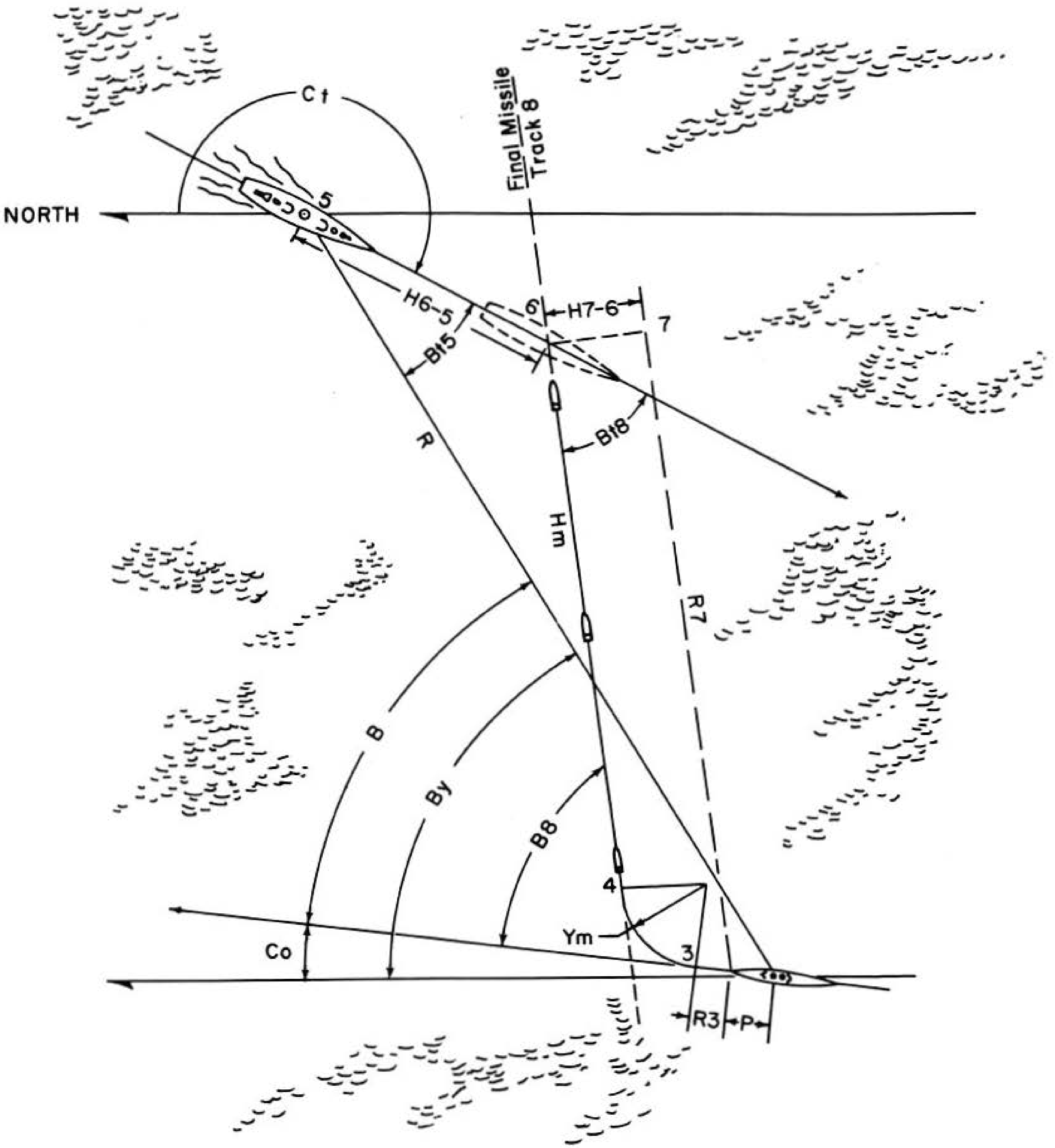


Figure 4—Use of Numbers in Submarine Firing of Torpedoes.

Table 6—Definitions of Symbols Used in Submarine Firing of Torpedoes

Symbol	Quantity	Definition
H6–5	Target run	Distance traveled by target during time of actual torpedo run.
R3	Reach	Initial straight path of torpedo.
Ym	Torpedo turning radius	Radius of circular torpedo path from end of initial straight path to beginning of final straight path.
Hm	Torpedo run	Distance which topredo actually travels along its path from end of tube to point of intercept with target.
R7	Semi-pseudo torpedo run.	Distance along a line parallel to final track of torpedo, measured from torpedo tube to a point abreast of point of impact.
H7–6	Torpedo advance	Perpendicular distance between final track of torpedo and line from torpedo tube muzzle parallel to this final track.
e(Hm)	Theoretical torpedo run	Distance a theoretical torpedo travels under water from tube muzzle in a given time. This theoretical torpedo is assumed to travel at a standard depth and at final running speed from instant it leaves muzzle.
j(Hm)	Torpedo run difference	Difference between theoretical torpedo run and actual torpedo run.
j(R7)	Torpedo angle difference.	Difference between torpedo run and semi-pseudo torpedo run.
B8	Gyro angle	Angle between own ship centerline and final torpedo track, measured clockwise from own ship centerline.
Bt8	Impact angle	Angle between target centerline and final torpedo track, measured clockwise from target centerline.

Chapter 2

LINEAR AND ANGULAR CORRECTIONS AND MODIFICATIONS

Navigational Parallax Corrections

Parallax corrections to position quantities accounting for displacement between the computing ship and the assisting ship are indicated by the quantity modifier ***pn***. The correction quantity differs from the basic navigational parallax quantity by being lower case rather than capitalized. To obtain the relative target bearing ***B*** from the assisting ship, the correction applied to the relative target bearing is symbolized by ***pn(B)***. Thus, ***B+pn(B)=(B)pn*** means that relative target bearing from the computing ship plus correction to relative target bearing for displacement between the computing ship and the assisting ship equals relative target bearing from the assisting ship.

Velocity Corrections

Velocity in Air. To express the constant air speed of the weapon (that is, the set running speed for a self-propelled missile through the air), the basic velocity symbol ***U*** is terminated by modifier ***f***, forming symbol ***Uf***.

To express the average air weapon velocity to the present and future target positions, numeral modifiers are applied to the air velocity symbol ***Uf***.

Velocity in Water. To express the constant water speed of the weapon (that is, the torpedo running speed), the basic velocity symbol ***U*** is terminated by modifier ***u***, forming symbol ***Uu***.

To express vertical velocities in water (that is, sinking speeds for depth charges, etc.), the water velocity symbol ***Uu*** is terminated by modifier ***v***, forming symbol ***Uuv***.

The running velocity of weapons may vary with the depth at which they are traveling. Torpedo speed is based on running at a specified proof depth, and when set for any other depth, the torpedo speed sometimes must be corrected. The correction to torpedo speed is expressed by enclosing the symbol ***Uu*** in parentheses, and preceding the parentheses with quantity modifier ***v***, forming symbol ***v(Uu)***.

To symbolize the corrected torpedo speed (that is, the speed including the depth correction), the symbol ***Uu*** is enclosed in parentheses and followed by quantity modifier ***v***, forming symbol ***(Uu)v***.

Thus, ***Uu+v(Uu)=(Uu)v*** means that torpedo speed at proof depth plus correction to torpedo speed for variation from proof depth equals torpedo speed corrected for torpedo running depth.

Other factors which affect the torpedo speed are water temperature and battery electrolyte temperature. The correction to torpedo speed for water temperature is expressed by enclosing the symbol ***Uu*** in parentheses and preceding the parentheses with quantity modifier ***jt***, forming symbol ***jt(Uu)***.

To symbolize the corrected torpedo speed (that is, the speed including the water temperature correction), the symbol ***Uu*** is enclosed in parentheses and followed by ***jt***, forming symbol ***(Uu)jt***.

Thus, ***Uu+jt(Uu)=(Uu)jt*** means that torpedo speed plus correction for water temperature equals torpedo speed corrected for water temperature.

The quantity modifier ***je*** is used to express correction for battery electrolyte temperature. The quantity modifier is applied in the same manner as described for water temperature modifier ***jt***.

Correction Quantities

Since present target position cannot be directly measured with sonar equipment, it is necessary to compute present target position quantities from the measured values of apparent position coordinates obtained from the sonar equipment. This usually is accomplished by computing corrections to apparent position

coordinates for the curvature of the sound beam as it passes through the water to obtain past target position, and then computing corrections to past target position coordinates for target travel during time of sound travel to own ship.

Apparent Position Corrections. The correction for curvature of the sound beam as it passes through the water is made by applying corrections to apparent position coordinates for temperature, pressure, and salinity gradients.

To express these individual corrections, the apparent position quantity is enclosed in parentheses and preceded by the appropriate quantity modifier.

The quantity modifiers with their meanings are:

MODIFIER	CORRECTION FOR
jt	Temperature
jp	Pressure
js	Salinity

For example, the correction to apparent position elevation ***Ea*** accounting for temperature is symbolized ***jt (Ea)***, for pressure ***jp (Ea)***, and for salinity ***js (Ea)***.

Thus, ***Ea + jt (Ea) + jp (Ea) + js (Ea) = jstp (Ea) = Ep*** means that apparent position elevation plus corrections to apparent position elevation for temperature, pressure, and salinity equals elevation of past target positions. It is seen that ***jstp (Ea) = Ep*** is an observation of fact, not a definition.

When symbolizing the total correction to an apparent position quantity accounting for temperature, pressure, and salinity, the lower case letters are applied to one ***j*** modifier, forming correction symbol ***jtps***. Thus, the total correction to apparent position elevation ***Ea*** for temperature, pressure, and salinity may be written ***jtps (Ea)***, and the preceding formula written ***Ea + jtps (Ea) = Ep***.

Past Target Position Corrections. The corrections to past target position coordinates accounting for target travel during the time of sound travel from target to own ship are made by enclosing the past target position quantity in parentheses, and preceding the parentheses with quantity modifier ***m***. For example, the correction to past target position elevation ***Ep*** accounting for target travel during time of sound travel is symbolized by ***m (Ep)***.

Thus, ***Ep + m (Ep) = E*** means that past target position elevation plus correction to past target position elevation for target travel during time of sound travel equals present target elevation.

Since

$$Ep = Ea + js(Ea) + jp(Ea) + jt(Ea)$$

then

$$E = Ea + js(Ea) + jp(Ea) + jt(Ea) + m(Ep)$$

$$E = Ea + jspt(Ea) + m(Ep)$$

Torpedo Run Difference. Torpedo run difference is the horizontal displacement between the actual torpedo and a theoretical torpedo fired at a standard depth and assumed to travel at final running speed from the instant of firing. That is, it is the difference between actual torpedo run and theoretical torpedo run.

This quantity is symbolized by enclosing the symbol for torpedo run ***Hm*** in parentheses and preceding the parentheses with quantity modifier ***j***, forming symbol ***j (Hm)***.

The total value of torpedo run difference is composed of two parts:

1. Displacement for the initial difference between the ejection velocity and the running velocity
2. Displacement for firing the actual torpedo at a depth other than standard or proof depth.

To symbolize these two parts of torpedo run difference, additional modifiers are applied to quantity modifier ***j***. Letter modifier ***m*** is used to indicate the part due to velocity difference, forming symbol ***jm (Hm)***, and letter modifier ***v*** is used for the part due to depth difference, forming symbol ***jv (Hm)***. Thus, ***jm (Hm) + jv (Hm) = j (Hm)***.

Maneuvering Quantities

Generally, the quantities discussed and symbolized in this volume are those used in the solution of the problem at some instant of firing.

In fixed range or limited train and elevation problems, such as ahead-thrown attacks, a prefiring phase is required in the solution. This phase involves the measurements and computations required to bring the launcher to a position where the weapon can be fired at the

target, and it is called the "maneuvering phase" of the problem.

Present Target Position Maneuvering Quantities. The quantities required to express target position during the maneuvering phase are exactly the same as those required to express target position during the firing phase. That is, bearings, elevations, and ranges are used to locate the target in a reference system. Therefore, in most instances, the symbols used for maneuvering quantities are exactly the same as the symbols used for firing quantities. These quantities are illustrated in figures 4 and 5 of Volume 1, and are symbolized and defined in composite tables 4A, 4B, and the table for figure 5.

In instances where it is necessary to distinguish between maneuvering and firing position quantities, the maneuvering quantities are symbolized as shown in Volume 1, tables 4A, 4B, and the table for figure 5. The corresponding firing quantities are symbolized by applying the numeral modifier ***1***, which is the number defining firing order, after the symbols shown in these tables. In Volume 1, table 5, target horizontal range is symbolized by ***Rh***, and during firing by ***Rh1***. Also, in table 4A, Volume 1, relative target bearing during maneuvering is symbolized by ***B***, and during firing by ***B1***.

The numeral modifier ***1*** is applied to position quantities during the firing phase only when a possibility of confusion between maneuvering and firing quantities exists. When no confusion is possible, the numeral modifier is eliminated from the firing quantities.

Sonar Maneuvering Quantities. As in the firing problem, when using sonar equipment to determine target position in the maneuvering problem the sonar transducer is not pointed at the target. Therefore, the required maneuvering target position quantities are computed from available sonar measurements.

The references, coordinates, and quantities required to express sonar position during the maneuvering phase are exactly the same as those required to express sonar position during the firing phase. Therefore, in most instances, the symbols for sonar maneuvering quantities are the same as the symbols for sonar firing quantities.

In instances where it is necessary to distinguish between sonar maneuvering and firing quantities, the same device is employed as for present position quantities. For example, horizontal range to apparent position is symbolized by ***Rha***. Therefore, horizontal range during maneuvering is symbolized by ***Rha***, and during firing by ***Rha1***.

As previously discussed, the numeral modifier ***1*** is applied to firing position quantities only in instances where there is a possibility of confusion between firing and maneuvering quantities. Where no confusion is possible, the modifier is omitted.

In fixed range or limited train and elevation problems where a maneuvering phase is required, the launcher is brought to the correct firing point by changing own ship course or heading.

Own Ship Course Correction. The value of own ship course during the maneuvering phase is symbolized by ***Co***. The amount own ship course is changed to bring own ship to the correct firing course is symbolized by enclosing own ship course symbol ***Co*** in parentheses, and preceding the parentheses with quantity modifier ***j***, forming symbol ***j(Co)***.

The value of own ship course during the firing phase (that is, the correct firing course) is symbolized by ***Col***. Thus, ***Co + j(Co) = Col*** means that own ship course during the maneuvering phase plus the change in course equals own ship firing course.

Own Ship Heading Correction. The value of own ship heading during the maneuvering and firing phases of the fixed launcher problem are symbolized in exactly the same manner as described for own ship course. That is, own ship heading during the maneuvering phase is symbolized by ***Cqo***, and during the firing phase by ***Cqol***. The change in own ship heading is symbolized by ***j(Cqo)***.

Thus, ***Cqo+j(Cqo)=Cqol*** means that own ship heading during the maneuvering phase plus change in heading equals own ship firing heading.

Torpedo Turning Radius Modification. Torpedo turning radius usually varies with left- and right-angle shots. To indicate left and right turning radius, basic symbol ***z*** is enclosed in parentheses and followed by modifiers.

Numeral modifier ***d*** is used for right turning radius, forming symbol **(*Ym*)*d*,** and numeral modifier ***e*** is used for left turning radius, forming symbol **(*Ym*)*e*.**

Time Remaining To Fire. In the present ahead-thrown and stern-dropped attacks, the solution is computed to obtain a correct time to fire the charge—that is, elapsed time between the present instant and the instant to fire the charge. To express this time quantity in terms of symbols, basic time symbol ***T*** is terminated by modifier ***n*,** forming symbol ***Tn*.**

DICTIONARY OF SYMBOLS

jstp(Bda′)

Correction to Relative Sonar Train

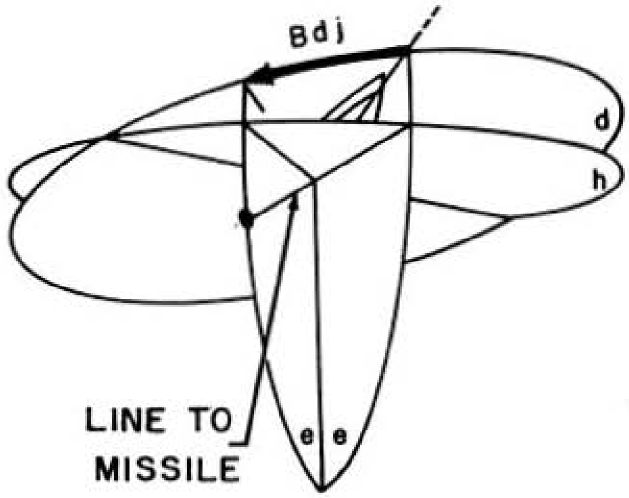
Correction applied to relative sonar train to account for temperature, pressure, and salinity gradients.

Note: To indicate the correction to any sonar position quantity for temperature, pressure, and salinity gradients, the quantity is enclosed in parentheses and preceded by quantity modifier ***jstp.***

Bdj

Relative Missile Bearing

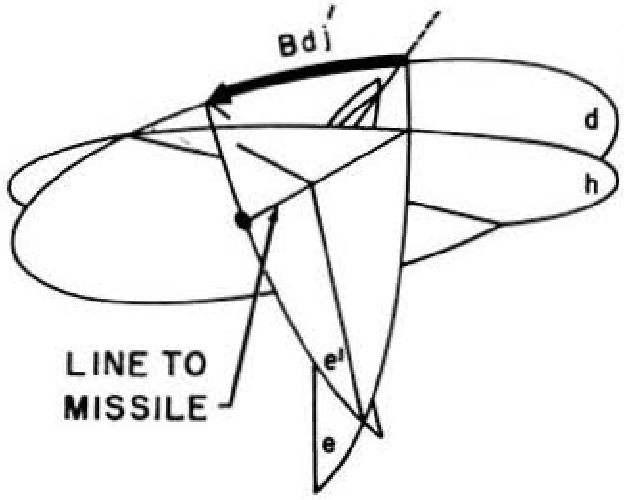
Angle between vertical plane through own ship centerline, and vertical plane through line to missile, measured in the deck plane. Positive angles measured clockwise from own ship centerline.



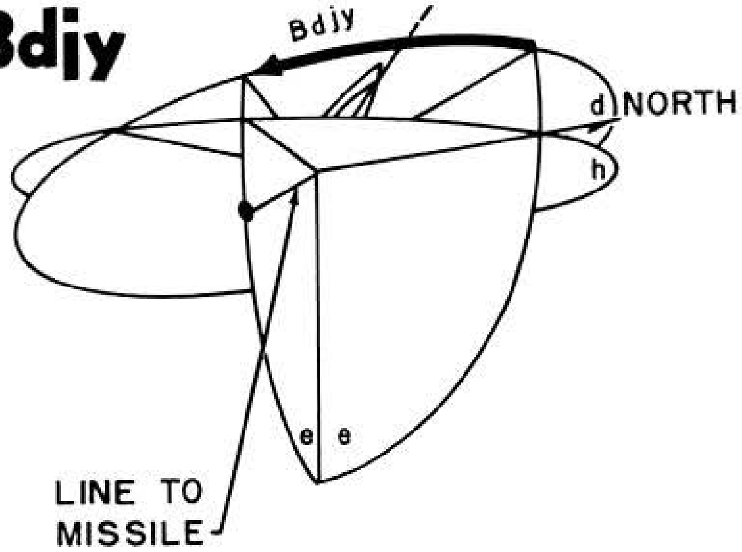
Bdj′

Relative Missile Bearing

Angle between vertical plane through own ship centerline, and normal plane through line to missile, measured in deck plane. Positive angles measured clockwise from own ship centerline.



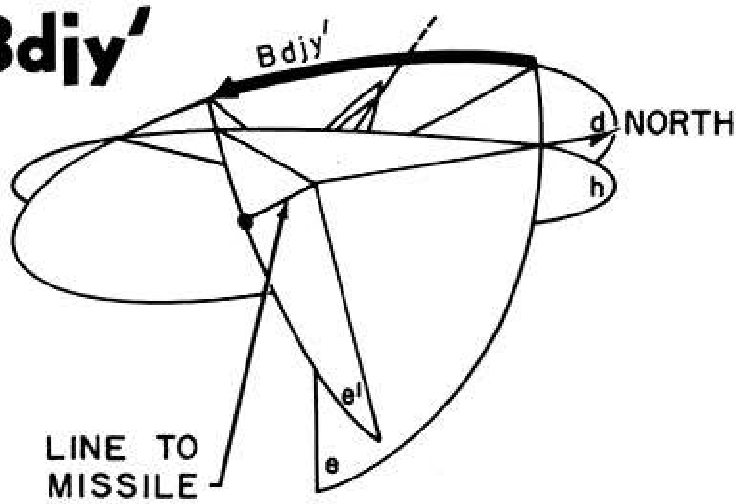
Bdjy



True Missile Bearing

Angle between North-South vertical plane and vertical plane through line to missile, measured in deck plane. Positive angles measured clockwise from North.

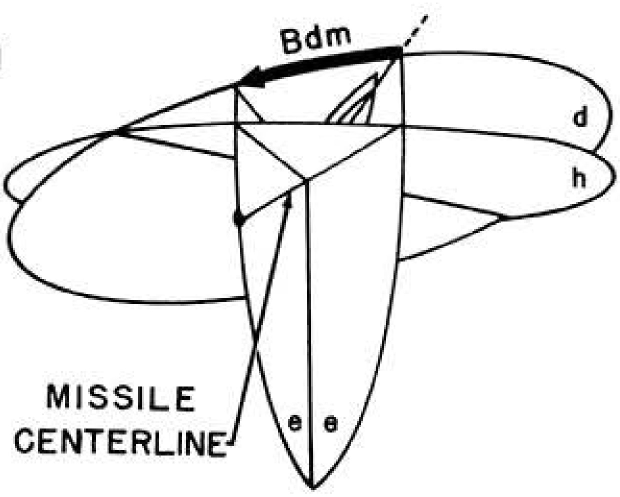
Bdjy'



True Missile Bearing

Angle between North-South vertical plane and normal plane through line to missile, measured in deck plane. Positive angles measured clockwise from North.

Bdm



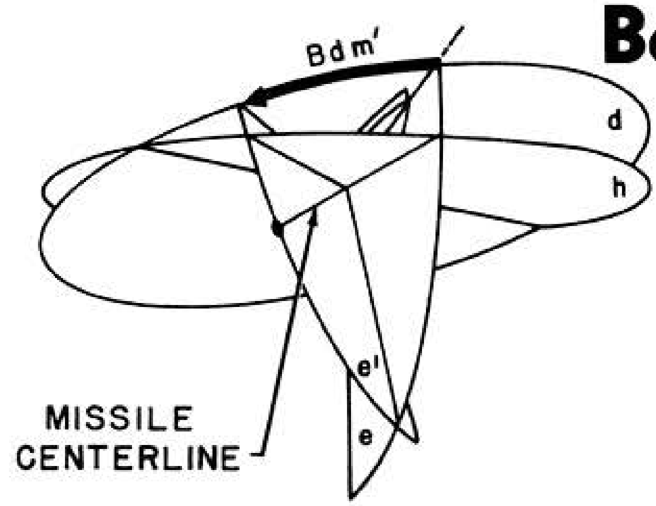
Missile Bearing

Angle vetween vertical plane through own ship centerline and vertical plane through missile speed vector, measured in deck plane. Positive angles measured clockwise from own ship centerline.

Bdm'

Missile Bearing

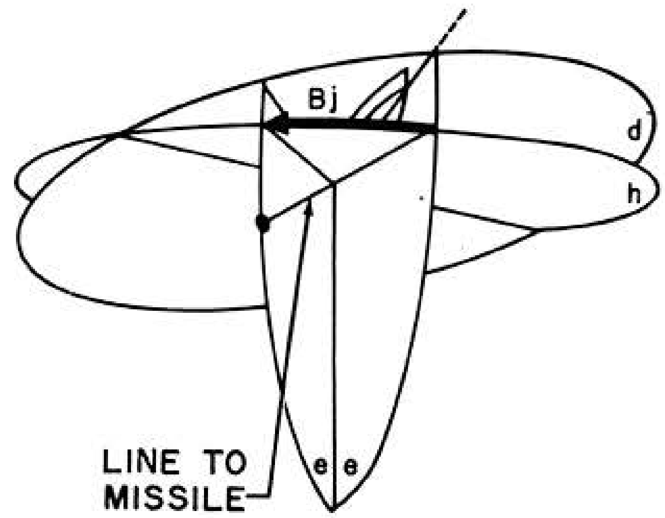
Angle between vertical plane through own ship centerline, and normal plane through missile speed vector, measured in deck plane. Positive angles measured clockwise from own ship centerline.



Bj

Relative Missile Bearing

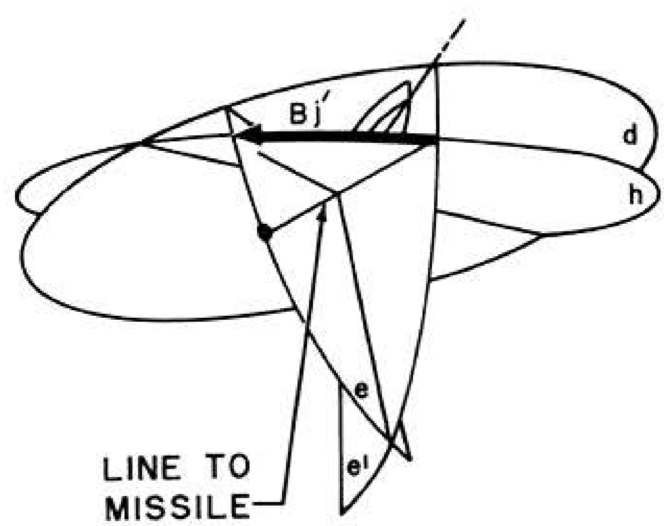
Angle between vertical plane through own ship centerline, and vertical plane through line to missile, measured in horizontal plane. Positive angle measured clockwise from own ship centerline.



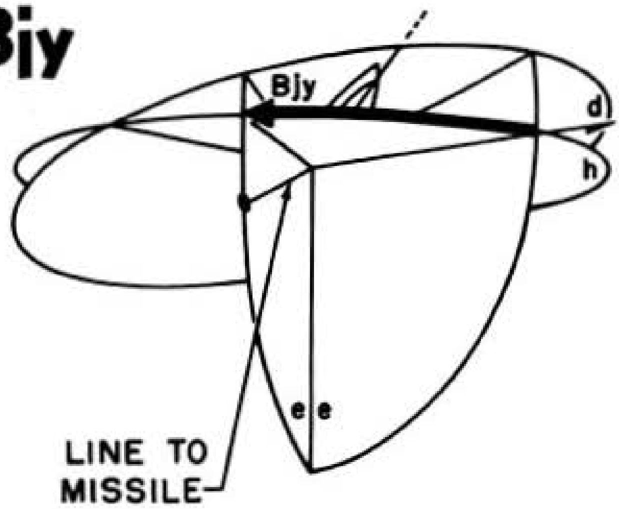
Bj'

Relative Missile Bearing

Angle between vertical plane through own ship centerline, and normal plane through line to missile, measured in horizontal plane. Positive angles measured clockwise from own ship centerline.



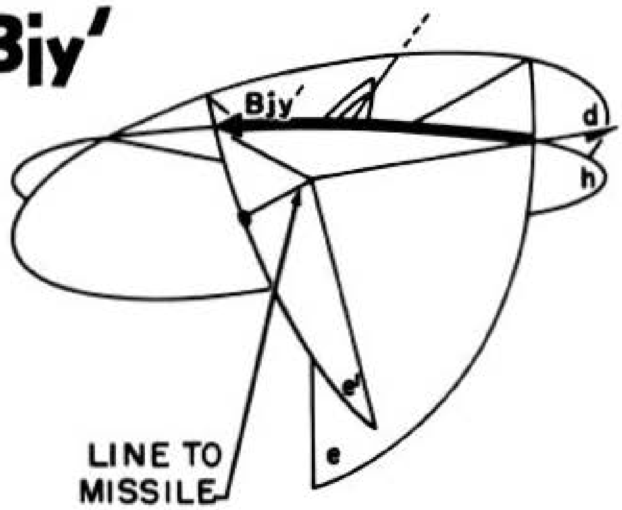
Bjy



True Missile Bearing

Angle between North-South vertical plane and vertical plane through line to missile, measured in horizontal plane. Positive angles measured clockwise from North.

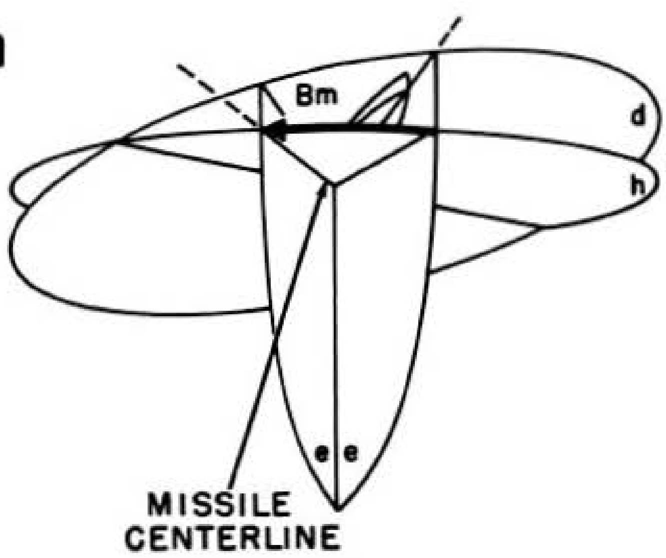
Bjy′



True Missile Bearing

Angle between North-South vertical plane and normal plane through line to missile, measured in horizontal plane. Positive angle measured clockwise from North.

Bm



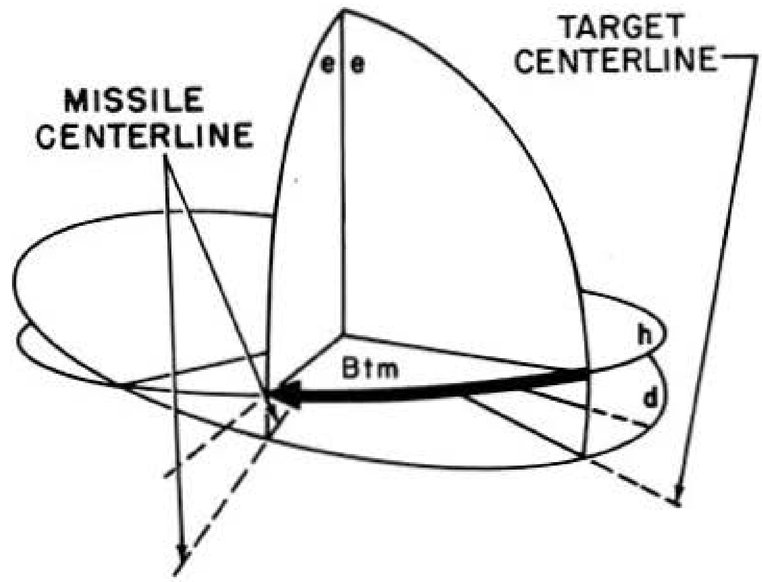
Relative Missile Bearing

Angle between vertical plane through own ship centerline, and vertical plane through missile speed vector, measured in horizontal plane. Positive angles measured clockwise from own ship centerline.

Btm

Relative Missile Bearing

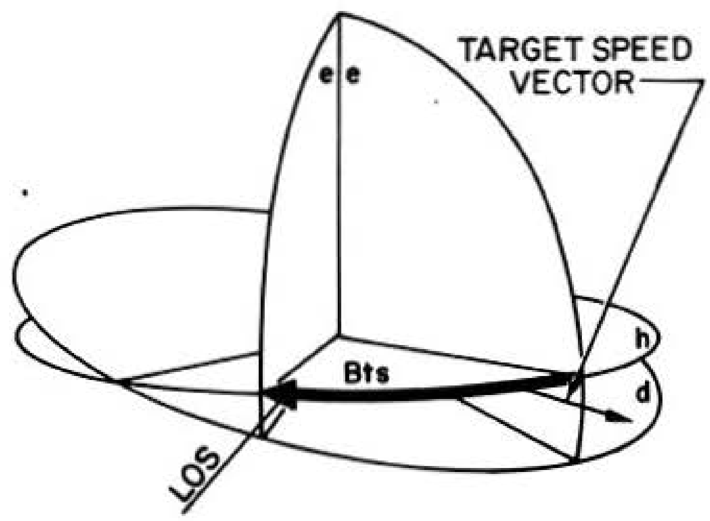
Angle between vertical plane through missile speed vector and vertical plane through target centerline. Positive angle measured clockwise from target centerline.



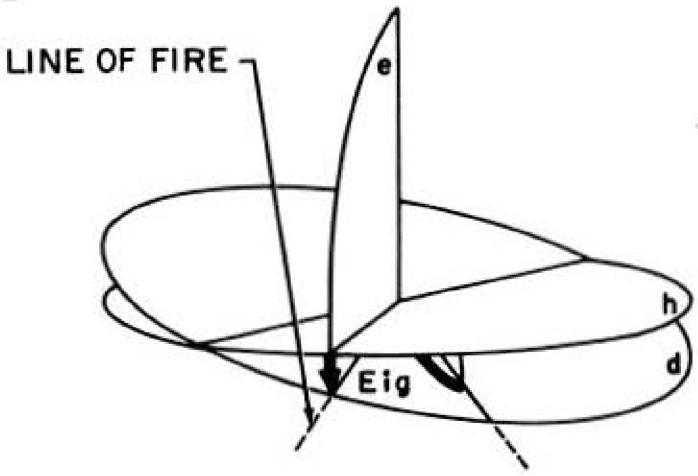
Bts

Target Angle

Angle between vertical plane through target speed vector, and vertical plane through line of sight, measured in horizontal plane clockwise from target speed vector.



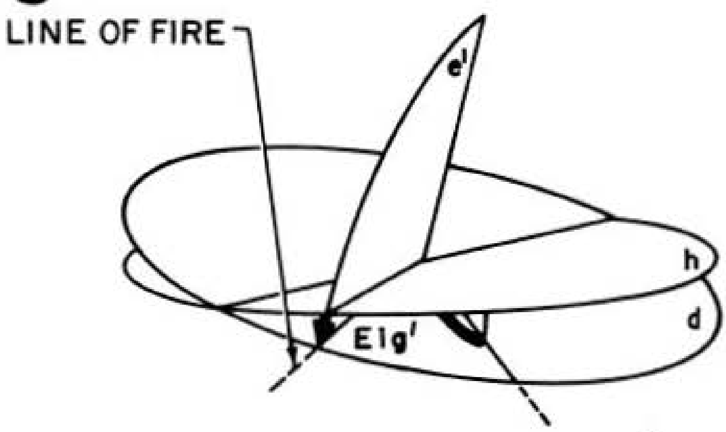
Eig



Level Angle

Angle between horizontal plane and deck plane, measured in vertical plane through line of fire. Positive angles measured downward from horizontal plane on target side of own ship.

Eig'



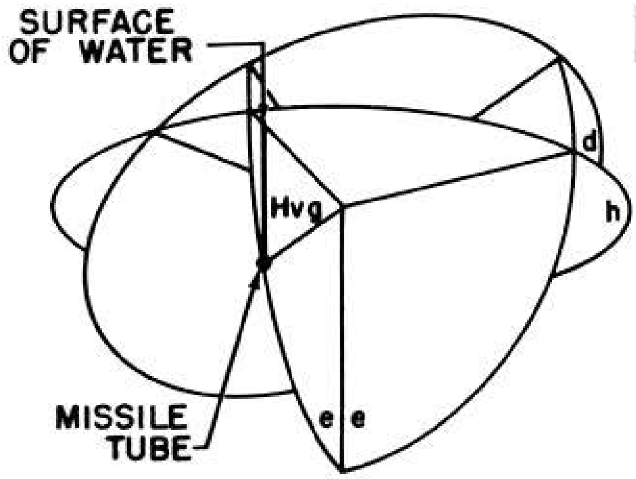
Level Angle

Angle between horizontal plane and deck plane, measured in normal plane through line of fire. Positive angles measured downward from horizontal plane on target side of own ship.

Hvg

Tube Depth

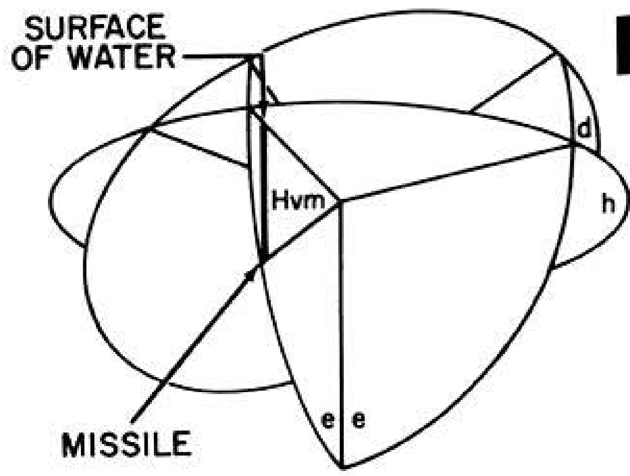
Vertical distance of torpedo tube below surface of water.



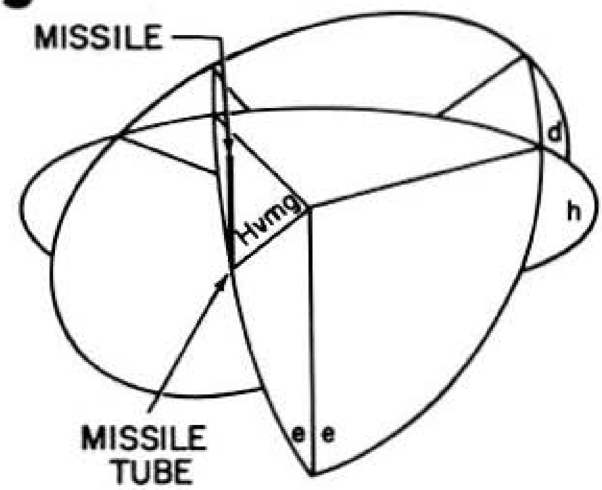
Hvm

Torpedo Running Depth Order

Vertical distance torpedo is set to run below surface of water.



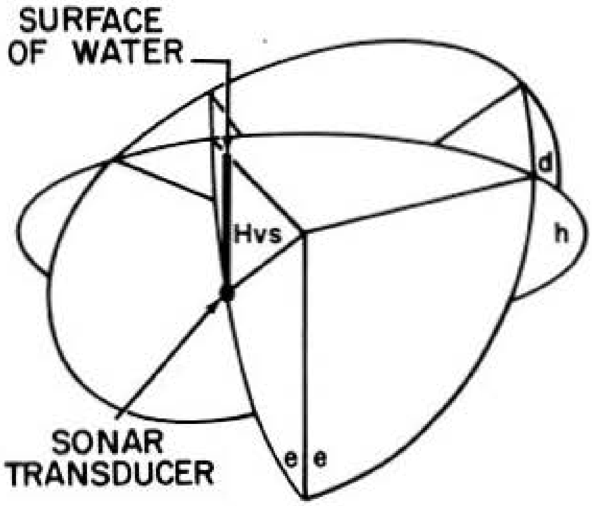
Hvmg



Depth Difference

Difference between depth of torpedo tube and running depth of torpedo. That is, $Hvmg = Hvg = Hvm$.

Hvs



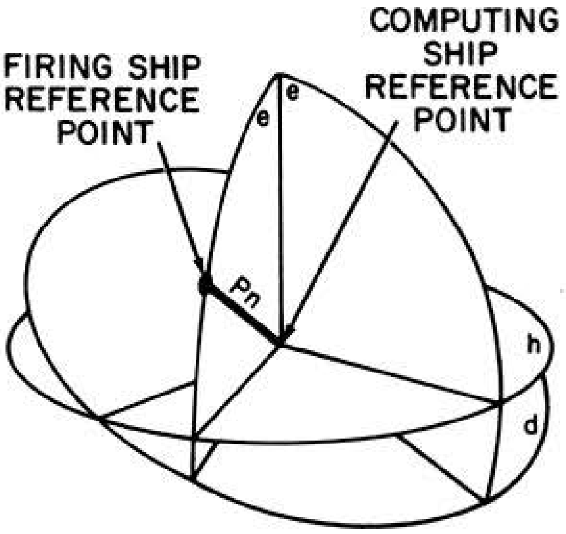
Transducer Depth

Vertical distance sonar transducer is below surface of water.

Pn

Navigational Parallax Base Length

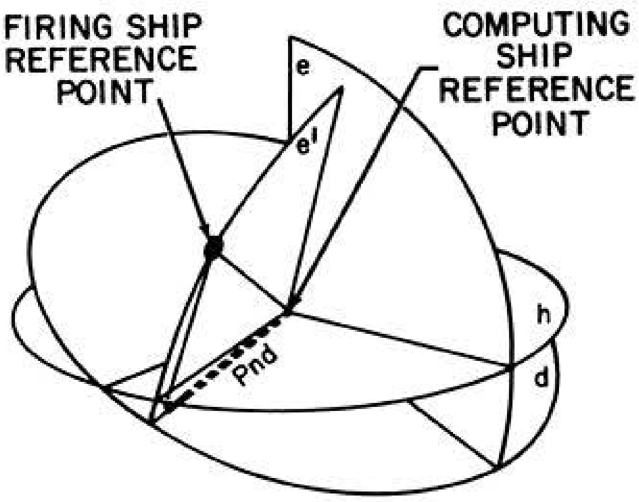
Total linear distance from reference point of computing ship to reference point of assist ship measured along navigational parallax base line.



Pnd

Deck Navigational Parallax

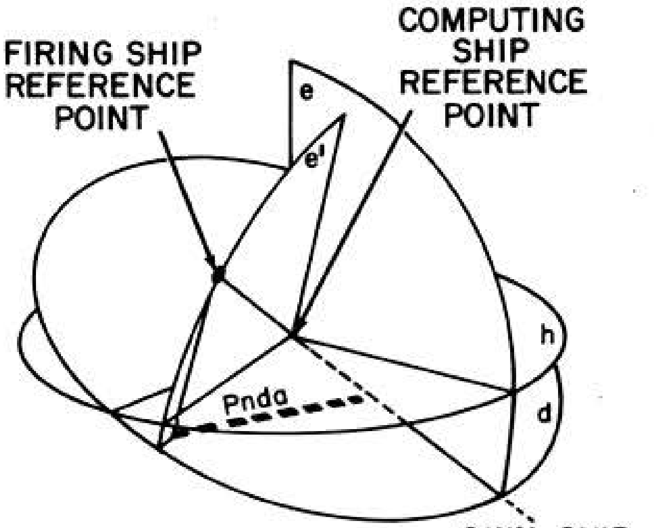
Projection of navigational parallax base length in deck plane by a normal plane through navigational parallax base line.



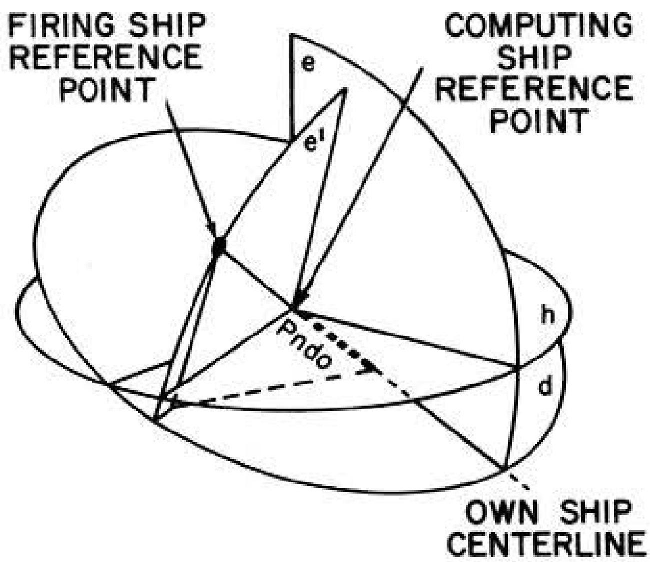
Pnda

Athwartship Navigational Parallax Displacement

Component of navigational parallax base length in deck plane perpendicular to vertical plane through own ship centerline.



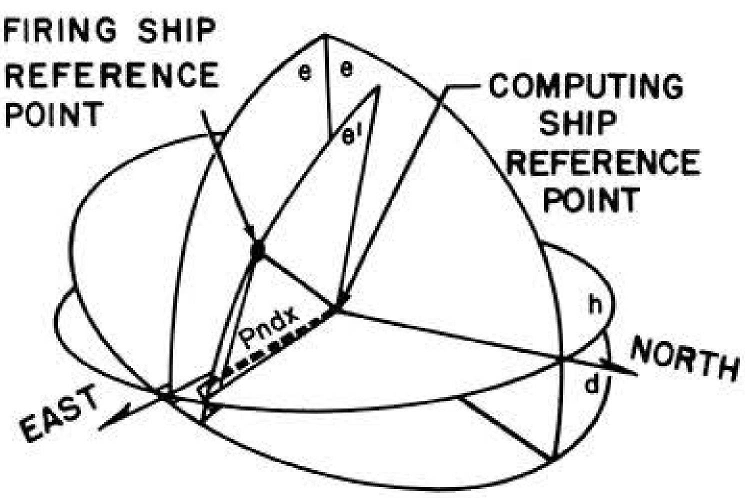
Pndo



Centerline Navigational Parallax Displacement

Component of navigational parallax base length in deck plane by a normal plane through own ship centerline.

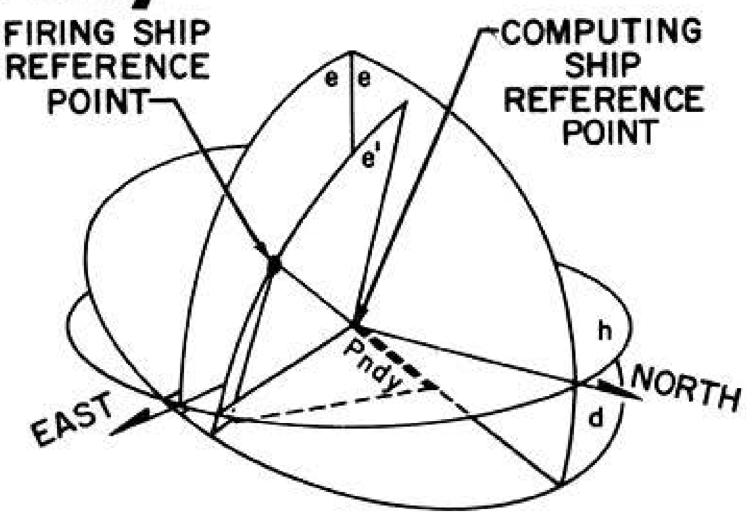
Pndx



East-West Deck Navigational Parallax Displacement

Component of navigational parallax base length in deck plane and in East-West normal plane.

Pndy



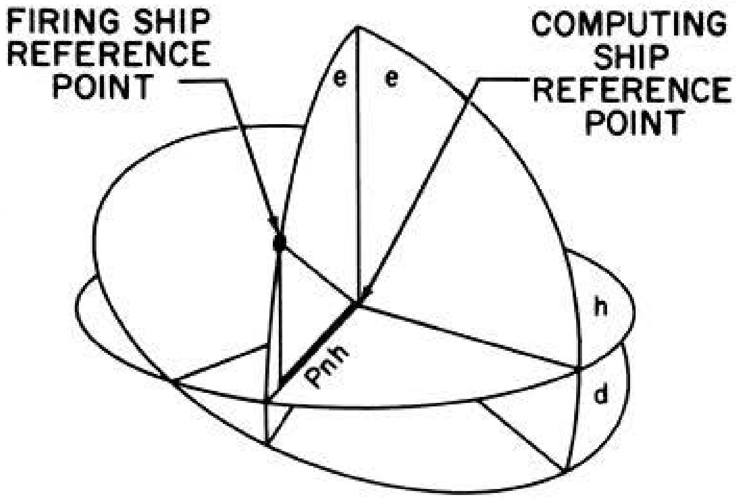
North-South Deck Navigational Parallax Displacement

Component of navigational parallax base length in deck plane and in North-South normal plane.

Pnh

Horizontal Navigational Parallax Displacement

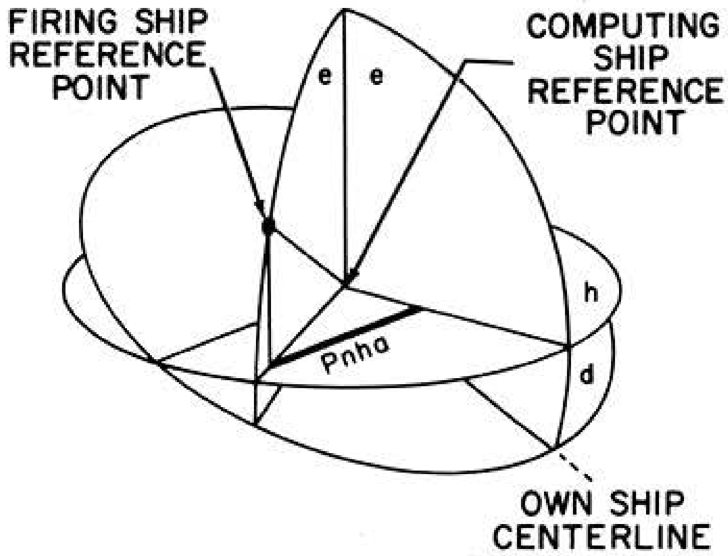
Projection of navigational parallax base length in horizontal plane by a vertical plane through navigational parallax base line.



Pnha

Athwartship Navigational Parallax Displacement

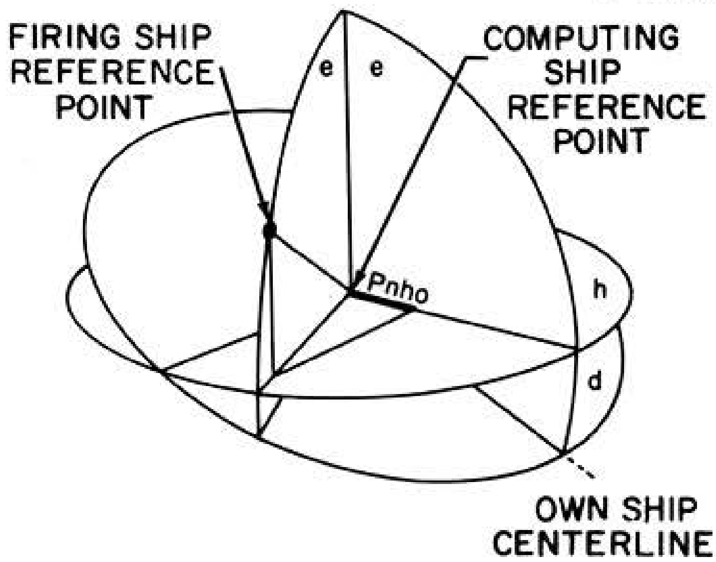
Component of navigational parallax base length in horizontal plane perpendicular to vertical plane through own ship centerline.



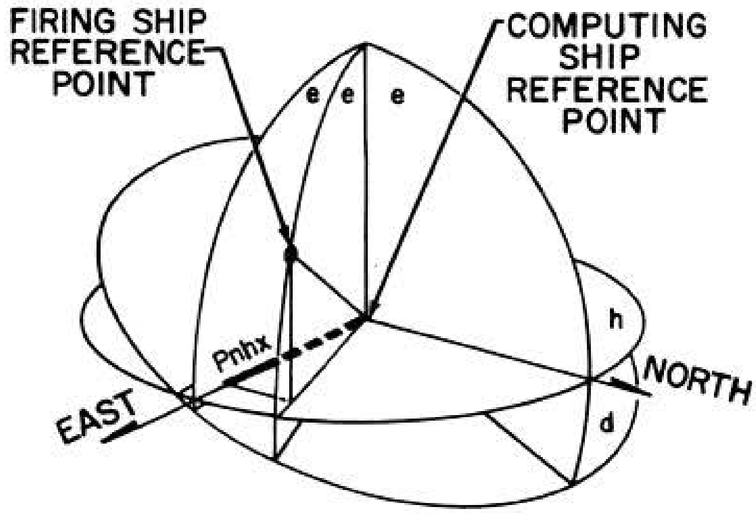
Pnho

Centerline Navigational Parallax Displacement

Component of navigational parallax base length in horizontal plane by a vertical plane through own ship centerline.



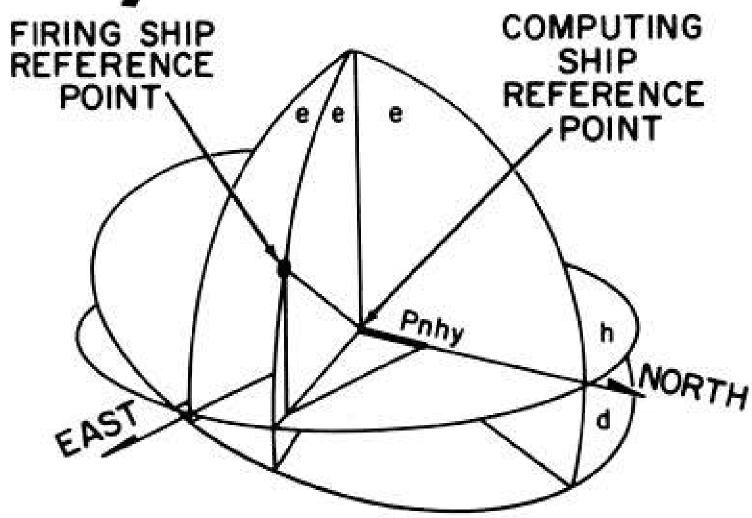
Pnhx



East-West Horizontal Navigational Parallax Displacement

Component of navigational parallax base length in horizontal plane and in East-West vertical plane.

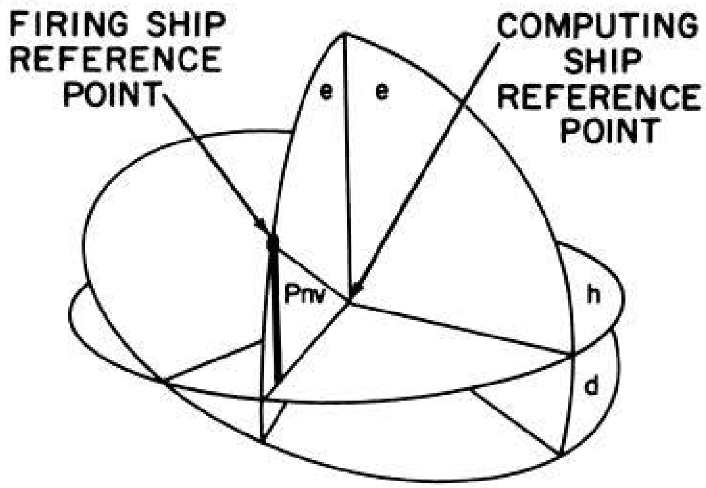
Pnhy



North-South Horizontal Navigational Parallax Displacement

Component of navigational parallax base length in horizontal plane and in North-South vertical plane.

Pnv



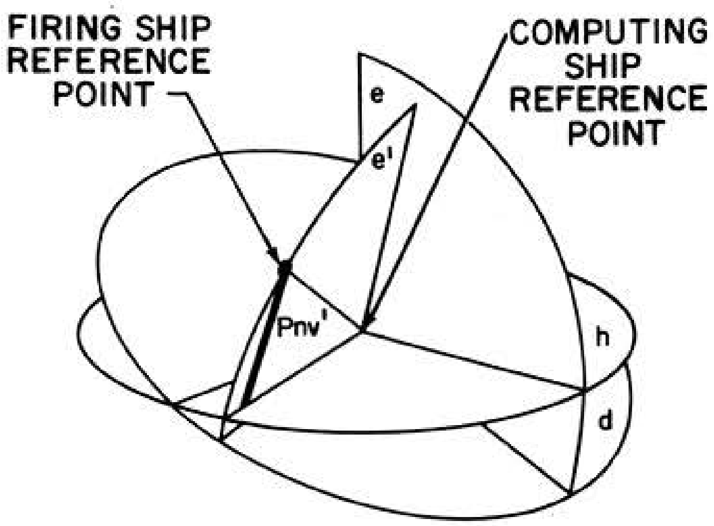
Vertical Navigational Parallax Displacement

Vertical component of navigational parallax base length measured from horizontal plane in vertical plane through navigational parallax base line.

Pnv′

Normal Navigational Parallax Displacement

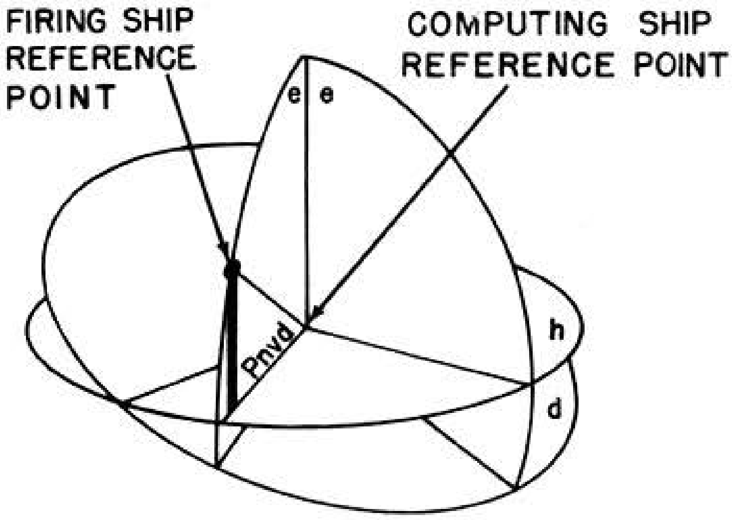
Normal component of navigational parallax base length measured from horizontal plane in vertical plane through navigational parallax base line.



Pnvd

Vertical Navigational Parallax Displacement

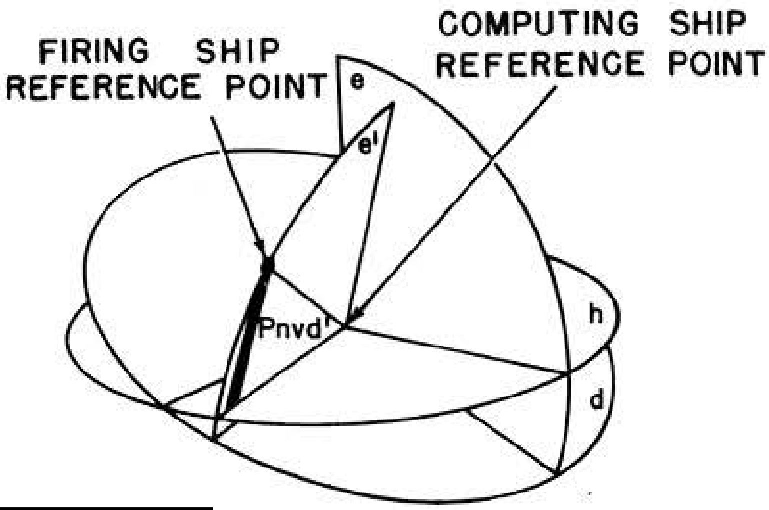
Vertical component of navigational parallax base length measured from deck plane in vertical plane through navigational parallax base line.



Pnvd′

Normal Navigational Parallax Displacement

Normal component of navigational parallax base length measured from deck plane in normal plane through navigational parallax base line.



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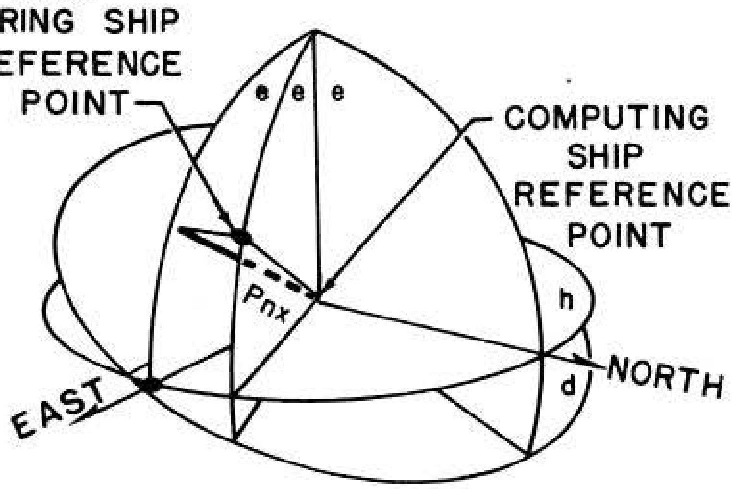
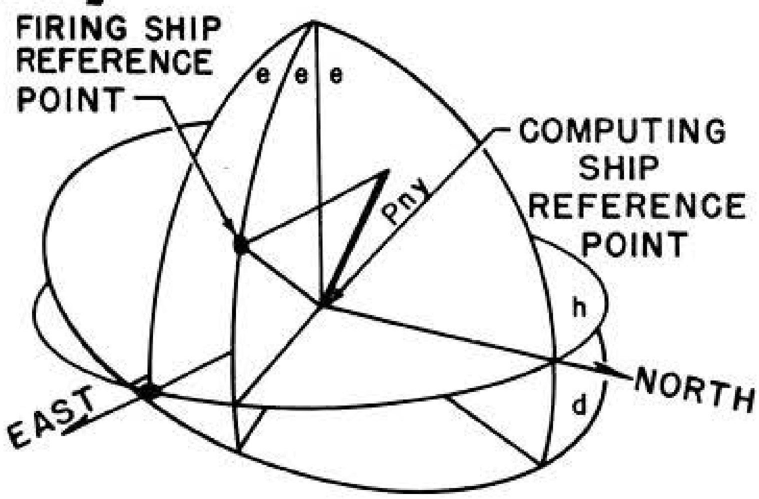
Pnx



East-West Navigational Parallax Displacement

Projection of navigational parallax base length in North-South vertical plane.

Pny



North-South Navigational Parallax Displacement

Projection of navigational parallax base length in North-South vertical plane.

Y

Radius of Turn

Radius of circular section of a track. Add ***o*** to indicate own ship turning radius. Add ***t*** to indicate target turning radius.

Ym

Missile Turning Radius

Radius of circular section of missile track. Circular section of missile track is measured from location of end of initial straight run to location of final missile track.

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Appendix A

BASIC SYMBOLS

Symbol	Name	Meaning when used alone
A	Angular movement in elevation.	Difference in elevation from horizontal plane between present line of sight and line to future target position, measured upward to line to future target position in a vertical plane.
B	Bearing	Relative bearing of target measured from vertical plane through own ship centerline to vertical plane through line of sight in horizontal plane clockwise from own ship centerline.
C	Course	Course of target from North-South vertical plane to vertical plane through relative target-speed vector in frame used by fire control system, measured in horizontal plane clockwise from North.
D	Rate of	Differentiating operator ***d/dt***.
E	Elevation	Elevation of target above horizontal plane measured upward from horizontal plane in vertical plane through line of sight.
Ei	Level	Angle between horizontal plane and deck plane, measured downward from horizontal plane (on target side of own ship) in vertical plane through line of sight.
F	Missile offset angle	Angle between line of sight to missile and line of sight.
G	Gyro angle	Angle between vertical plane through line of fire and vertical plane through desired missile centerline measured in horizontal plane.
H	Distance	Basic symbol used with modifiers to define distance between two points.
I	Angle of inclination	Useful only as a rate; ***DI*** expresses rate of rotation of own ship with respect to earth frame.
J	Jump deviation	No meaning.
L	Sight deflection	Total lead angle between line of sight and line of fire.
M	Linear movement	Total linear displacement of target during time of flight due to relative motion between own ship and target in frame used by fire control system.

Appendix A—Continued

BASIC SYMBOLS—Continued

Symbol	Name	Meaning when used alone
N		
O		
P	Firing parallax base	Total linear displacement between reference point and gun measured along firing parallax base line.
Pn	Navigational parallax base length.	Total linear displacement between computing-ship reference point and firing-ship reference point.
Ps	Position parallax base length.	Total linear displacement between reference point and sighting element measured along position parallax base line.
Q		
R	Range	Distance between own ship and target measured along line of sight.
S	Lateral angular movement.	Total angular displacement measured from line of sight to line to future target position.
T	Time	Elapsed time.
U	Velocity	Initial velocity of projectile with respect to gun muzzles at instant projectile leaves gun.
V	Sight angle	Difference in elevation between line of sight and line of fire measured in a vertical plane.
W	Wind rate	Total rate of true wind measured with respect to the earth.
X		
Y	Radius of turn	Distance from center of a turning arc to the arc.
Z	Cross level	Angle between vertical plane through line of sight, and normal plane through intersection of vertical plane through line of sight and horizontal plane, measured about an axis which is intersection of vertical plane through line of sight and horizontal plane.

BASIC SYMBOL MODIFIERS

Modifier	Name	Used to indicate
a	Apparent or athwartship	Quantities related to apparent target position or apparent wind, or quantities related to athwartship components of parallax.
b	Bearing	Quantities in direction affecting bearing.
c		
d	Deck	Quantities measured in, from, or about axes in the deck.
e	Elevation	Quantities in direction affecting elevation.
f	Flight, Air	Quantities related to weapon flight through the air.
g	Gun or launcher	Quantities measured from, to, or about line of fire.
h	Horizontal	Quantities measured in horizontal plane.
i		
j	Line of sight to missile	Quantities measured from, to, or about line of sight to missile.
k	Earth	Quantities expressing earth rates.
l		
m	Missile	Quantities measured from, to, or about missile centerline.
n		
o	Own ship	Quantities measured from, to, or about own ship centerline, and quantities expressing own ship rates and own ship wind rates.
p	Past	Quantities related to past target position.
q	Heading	Compass head of own ship or target.
r	Range	Quantities in direction affecting range.
s	Line of sight	Quantities measured from, to, or about line of sight or director.

Appendix B—Continued

BASIC SYMBOL MODIFIERS—Continued

Modifier	Name	Used to indicate
t	Target	Quantities measured from, to, or about target centerline, and quantities expressing target rates.
u	Underwater	Quantities expressing rates, angles, etc., of underwater weapons.
v	Vertical	Quantities in vertical direction.
w	Wind	Quantities related to wind.
x	East-West	Quantities measured in East-West direction.
y	North-South	Quantities measured from North or in a North-South direction.
z	Cross level	Quantities related to cross roll.
'	Prime (before quantity)	Measurement from a normal plane.
'	Prime (after quantity)	Measurement to or in a normal plane.
''	Double prime (before quantity)	Measurement from a plane normal to the slant plane.
''	Double prime (after quantity)	Measurement to or in a plane normal to the slant plane.
0	Will to fire	Quantities measured with respect to will or intent to fire or optimum time to fire.
1	Firing order	Quantities measured with respect to physical action of firing, i. e., closure of firing key, or any action which initiates an irretrievable firing sequence.
2	Fire	Quantities measured with respect to firing, i. e., ignition.

Appendix C

QUANTITY MODIFIERS

These modifiers are used before or after parentheses.

Modifier	Name	Before the parentheses	After the parentheses
a	Advance	Portion of quantity measured to advance position.	No meaning.
b	Ballistics	Portion of quantity accounting for superelevation or drift.	The quantity corrected for the effect of superelevation or drift.
c	Computed or generated.	Value of a quantity as computed or generated in the mechanism.	No meaning.
d	Designated	Designated value of the quantity.	Right.
e	Estimated or error	Estimated value of quantity or error in that quantity.	Left.
f	Function	Function of the quantity	No meaning.
g	Dead time	Correction to quantity due to dead time.	The quantity corrected for the effect of dead time.
h			
i	Increment	Increment of the quantity	No meaning.
j	Computational addition or partial.	Computational addition to the quantity.	A partial value of the quantity.
je	Battery electrolyte temperature.	The portion of that quantity accounting for battery electrolyte temperature.	The quantity corrected for effect of battery electrolyte temperature.
jm	Velocity difference	The portion of that quantity accounting for velocity difference.	The quantity corrected for effect of velocity difference.
jp	Water pressure	The portion of that quantity accounting for change in water pressure.	The quantity corrected for change in water pressure.

Appendix C—Continued

QUANTITY MODIFIERS—Continued

Modifier	Name	Before the parentheses	After the parentheses
js	Salinity	The portion of that quantity accounting for change in salinity.	The quantity corrected for change in salinity.
jt	Water temperature.	The portion of that quantity accounting for water temperature.	The quantity corrected for change in water temperature.
jv	Depth difference	The portion of that quantity accounting for depth difference.	The quantity corrected for change in depth difference.
k	Earth	No meaning	The quantity referred to the earth frame.
I	Initial	The initial value of the quantity	No meaning.
m	Relative motion	The portion of that quantity accounting for relative motion between own ship and target.	The quantity corrected for effect of relative motion between own ship and target.
n	Reach	That portion of the quantity accounting for reach.	The quantity corrected for effect of reach.
o	Observed or measured.	The observed or measured value of the quantity.	Referred to a frame rigidly attached to own ship.
p	Firing parallax	The portion of the quantity accounting for firing parallax.	The quantity corrected for the effect of firing parallax.
pn	Navigational parallax.	The portion of the quantity accounting for navigational parallax.	The quantity corrected for effect of navigational parallax.
ps	Position parallax	The portion of the quantity accounting for position parallax.	The quantity corrected for effect of position parallax.
q	Corrective input or spot.	A corrective input or spot to the quantity.	No meaning.
r	Rate control	Rate control correction to a quantity.	The quantity including the rate control correction.

Appendix C—Continued

QUANTITY MODIFIERS—Continued

Modifier	Name	Before the parentheses	After the parentheses
s	Selected	A selected value of the quantity.	Referred to the inertial frame.
u	Initial velocity loss.	The portion of the quantity accounting for change in initial velocity.	The quantity corrected for change in initial velocity.
v	Height or depth	The portion of that quantity accounting for change in height or depth.	The quantity corrected for change in height or depth.
w	Wind	The portion of the quantity accounting for effect of wind.	The quantity corrected for effect of wind.
x	Run difference	The portion of the quantity accounting for run difference.	The quantity corrected for effect of run difference.
y	Turning	The portion of the quantity accounting for turning radius.	The quantity corrected for effect of turning radius.
z			

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21 January 1958/6500/1

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OP 1700 (VOL. 3)

STANDARD FIRE CONTROL SYMBOLS

FOR

MISSILE RELATED QUANTITIES

Gene Slover's US Navy Pages

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6 DECEMBER 1957

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DEPARTMENT OF THE NAVY

BUREAU OF ORDNANCE

WASHINGTON 25, D. C.

6 December 1957

ORDNANCE PAMPHLET 1700 (VOLUME 3)

STANDARD FIRE CONTROL SYMBOLS FOR MISSILE RELATED QUANTITIES

1. The Ordnance Pamphlet 1700 series establishes and standardizes fire control symbols used in describing fire control problems and their solutions for the control of guns, underwater weapons, and missiles. Volume 3 contains the standardized symbols peculiar to control of missiles.

2. This publication is intended for use by all personnel concerned with applications of missile control symbols.

3. The OP 1700 series includes two other volumes:
   - OP 1700 (Volume 1) Standard Fire Control Symbols
   - OP 1700 (Volume 2) Standard Fire Control Symbols for Underwater Related Quantities.

4. This publication must be used in conjunction with OP 1700 (Volume 1) "Standard Fire Control Symbols"; symbols described therein are common to both gun and missile control, and are not repeated in this volume.

5. This publication, together with OP 1700 (Volumes 1 and 2) supersede NAVORD OD 3447, which shall be destroyed.

F. S. Withington

John Quinn

JOHN QUINN
Rear Admiral, U. S. Navy
Deputy Chief, Bureau of Ordnance

Gene Slover's US Navy Pages

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INTRODUCTION

This volume includes the requirements for symbols expressing the quantities involved in each step of the general missile fire control problem, and any difficulties which arise in symbolizing these quantities. Also, it establishes the standard symbols for all existing missile fire control quantities. For ready reference to the classes of quantities used in any specific part of the missile fire control problem, the classes (with all the individual quantities in each class) are grouped compositely under the part of the fire control problem in which they are involved. For example, if it is desired to have at hand the classes of quantities (with all the quantities in each class) used to express present missile position, reference is made to the page or pages showing this group of quantities.

To accomplish this, this volume is divided into five chapters; each chapter being one of the steps in the solution of a general missile fire control problem:

1. Present Target and Missile Positions
2. Motion
3. Wind
4. Offset and Launcher Orders
5. Guidance

Included in each chapter are:

1. The standard references and geometrical elements necessary to symbolize the quantities involved.
2. The classes of quantities with the basic symbol used to represent each.
3. The definition of the basic symbol when representing the basic quantity in each class.
4. The basic symbol modifiers and quantity modifiers with their exact meanings when used with each basic symbol.
5. Examples of the application of basic symbol modifiers and quantity modifiers when used with each basic symbol.
6. Composite illustrations and charts for each class of quantities, defining and symbolizing the quantities involved.

For clarity in designating planes in the composite illustrations, color-coding and letter designations are used. The colors and letters used are:

h	red	horizontal plane
d	green	deck plane
e	light blue	vertical plane
e'	yellow	normal plane
s	orange	slant plane through director elevation axis in horizontal plane
sd	purple	slant plane through director elevation axis in deck plane
g	brown	slant plane through gun elevation axis in horizontal plane
gd	indigo blue	slant plane through gun elevation axis in deck plane

Chapter 1

PRESENT TARGET AND MISSILE POSITIONS

To determine present target and missile positions, the missile and the target are located in reference frames by systems of coordinates. In naval fire control, reference frames originate on own ship and on the missile. Target position is measured with respect to either a point on own ship (own ship reference point) or a point on the missile (missile reference point); missile position is measured with respect to own ship reference point.

Reference planes used for the measurements of present target and missile positions are:

1. Horizontal plane
2. Own ship deck plane
3. Missile deck plane, i. e. that plane in missile considered equivalent to own ship's deck plane

Reference lines used are:

1. Vertical, perpendicular to the horizontal plane
2. Normal, perpendicular to the own ship deck plane
3. Normal, perpendicular to the missile deck plane
4. Own ship centerline
5. Missile centerline
6. North-South line

Systems of Coordinates

Systems of coordinates used for measurement are spherical, cylindrical, and cartesian coordinates, as described in volume 1, chapter 1 under antiaircraft related quantities.

At present these are the only coordinate systems which are used in fire control systems. The use of other coordinates is described in appendix E, also the rotation of coordinate frames.

Target and missile bearings. To the target bearings from own ship described in volume 1, chapter 1, must be added missile bearings from own ship (see figure 1 and table 1), and target bearings from missile (see figure 2 and table 2). In symbolizing these bearings, the basic bearing symbol, ***B,*** is used, together with the additional missile modifier, ***m.*** When ***m*** follows ***B,*** as in ***Bm,*** a missile bearing from own ship is indicated; when ***m*** precedes ***B,*** as in ***mB,*** a target bearing from missile is indicated.

In figure 1, bearing angles expressing present missile position with respect to own ship are shown with numerals indicating the arc measuring the angle. In composite table 1, each bearing angle is symbolized and defined. For example, in figure 1, bearing of the missile from the N–S vertical plane to the vertical plane through the line of sight to the missile (LSM) measured in the horizontal plane is illustrated as the angle 1–5. In composite table 1, this angle is defined and symbolized ***Bmy.***

In figure 2, bearing angles expressing present target position with respect to the missile are shown with numerals indicating the arc measuring the angle. In composite table 2, each bearing angle is symbolized and defined. For example, in figure 2, bearing of the target from the N–S vertical plane to the vertical plane through the line of sight from missile to target (LMT) measured in the horizontal plane is illustrated as the angle 1–5. In composite table 2, this angle is defined and symbolized ***mBy.***

Target and Missile Elevations. To the target elevations from own ship described in volume 1, chapter 1, must be added missile elevations from own ship (see figure 1 and table 3), and target elevations from missile (see figure 2 and table 4). In symbolizing these elevations the basic elevation symbol, ***E,*** is used, together with the additional missile modifier, ***m.*** When ***m*** follows ***E,*** as in ***Em,*** a missile elevation from own ship is indicated; when ***m*** precedes ***E,*** as in ***mE,*** a target elevation from missile is indicated.

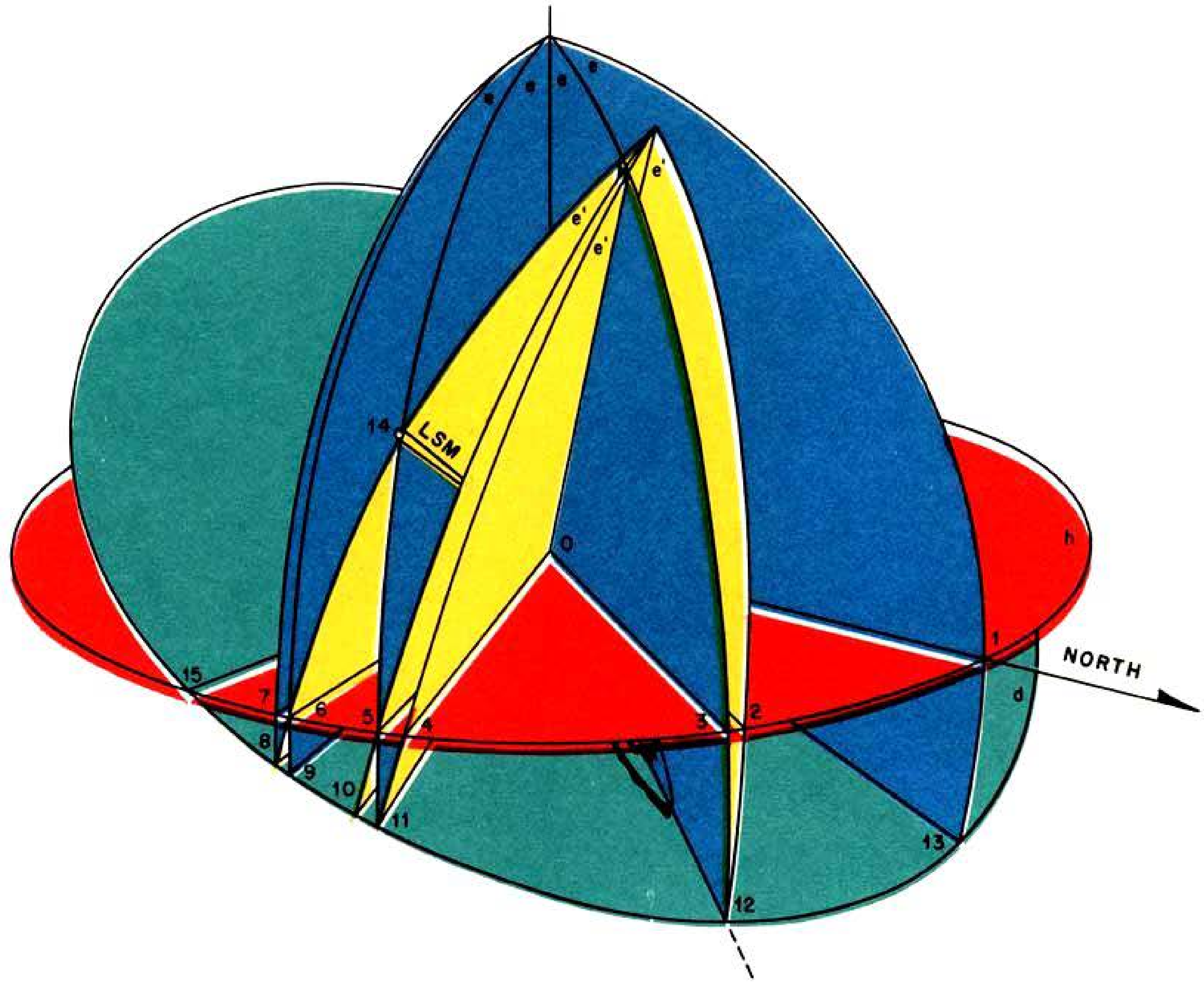

Figure 1—Angular Missile Coordinates and Deck Inclination.

Table 1

			To vertical plane through LSM	To normal-to-deck plane through LSM
Missile bearing from own ship	In horizontal plane	From N–S vertical plane	***Bmy*** 1–5	***Bmy′*** 1–6
		From vertical plane through OSCL	***Bm*** 3–5	***Bm′*** 3–6
	In own ship deck plane	From N–S vertical plane	***Bdmy*** 13–11	***Bdmy′*** 13–8
		From vertical plane through OSCL	***Bdm*** 12–11	***Bdm′*** 12–8

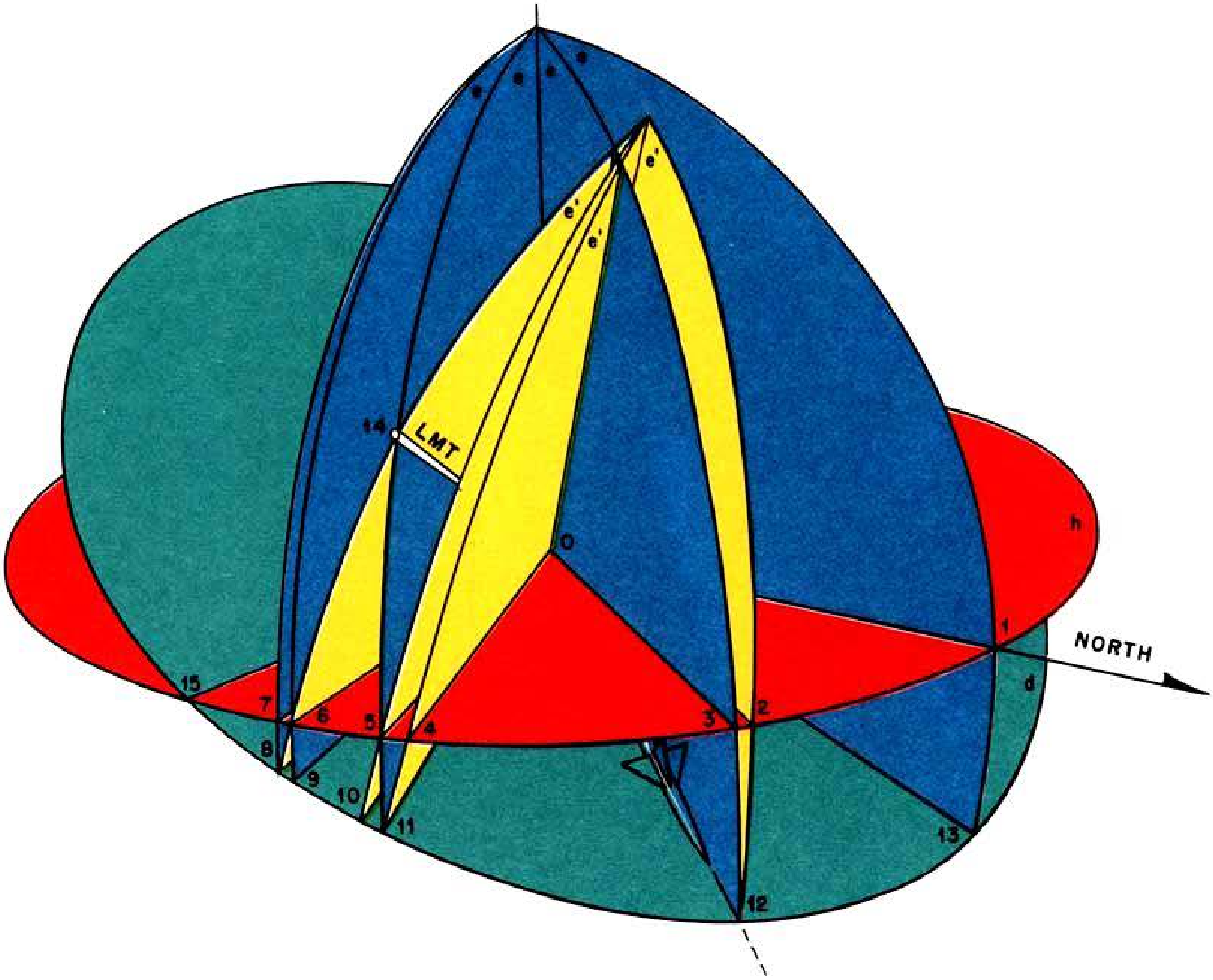

Figure 2—Angular Target-from-Missile Coordinates and Missile Deck Inclination.

Table 2

			To vertical plane through LMT	To normal-to-missile-deck plane through LMT
Target bearing from missile	In horizontal plane	From N–S vertical plane	***mBy*** 1–5	***mBy′*** 1–6
		From vertical plane through MCL	***mB*** 3–5	***mB′*** 3–6
	In missile deck plane	From N–S vertical plane	***mBdy*** 13–11	***mBdy′*** 13–8
		From vertical plane through MCL	***mBd*** 12–11	***mBd′*** 12–8

In figure 1, elevation angles expressing present missile position with respect to own ship are shown with numerals indicating the arc measuring the angle. In composite table 3, each elevation angle is symbolized and defined. For example, in figure 1, elevation of the missile above the own ship deck plane measured in the vertical plane through the line of sight to the missile (LSM) is illustrated as the angle 11–14. In composite table 3, this angle is defined and symbolized ***Edm***.

In figure 2, elevation angles expressing present target position with respect to the missile are shown with numerals indicating the arc measuring the angle. In composite table 4, each elevation angle is symbolized and defined. For example, in figure 2, elevation of the target above the missile deck plane measured in the vertical plane through the line of sight from missile to target (LMT) is illustrated as the angle 11–14. In composite table 4, this angle is defined and symbolized ***mEd***.

Indeterminate Angular Coordinates. The sighting operation, as described in volume 1, chapter 1 and in the two preceding paragraphs, consists of two successive rotations, bearing and elevation, about well-defined axes in the sighting mechanism. The bearing axis is perpendicular to either the horizontal or the deck plane (this paragraph is concerned only with sighting from own ship, and so deck plane is own ship deck plane wherever it is used); the elevation axis is perpendicular to either the vertical plane or the normal-to-deck plane through the line of sight.

Table 3

		In vertical plane through LSM	In normal-to-deck plane through LSM
Missile elevation from own ship	From horizontal plane	5–14 ***Em***	6–14 ***Em'***
	From own ship deck plane	11–14 ***Edm***	8–14 ***Edm'***

Table 4

		In vertical plane through LMT	In normal-to-missile-deck plane through LMT
Target elevation from missile	From horizontal plane	5–14 ***mE***	6–14 ***mE'***
	From missile deck plane	11–14 ***mEd***	8–14 ***mEd'***

Newer sighting mechanisms, however, establish a line of sight by means of three successive rotations, bearing, elevation, and traverse. The bearing axis is still perpendicular to the horizontal or deck plane, but the terminal plane of the bearing rotation, instead of being a vertical or normal plane through the line of sight, is now an arbitrary vertical or normal plane. The new elevation axis is perpendicular to the bearing terminal plane, but since this plane no longer contains the line of sight, the elevation rotation must now have a terminal plane, which is a slant plane through the line of sight. The traverse axis is perpendicular to this slant plane, and the traverse rotation therefore terminates at the line of sight. Note that the slant plane is normal to the bearing terminal plane, not the vertical plane through the line of sight.

The angular coordinates thus defined are

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called "indeterminate" bearing, "indeterminate" elevation, and "indeterminate" traverse. (See figure 3.) This is because it is not possible to compute, from the initial and final positions of the line of sight, what are the three individual rotations: bearing, elevation, and traverse. They may be used by mechanisms sighting either the target or the missile from own ship. In symbolizing these coordinates, the basic bearing and elevation symbols, ***B*** and ***E***, and ***Bs***, representing traverse, are enclosed in double parentheses to indicate that they are indeterminate. The additional missile modifier, ***m***, following the basic symbol, is used to indicate a missile coordinate from own ship; without it, target coordinates are understood.

In figure 3, indeterminate bearing, elevation, and traverse angles expressing present target position with respect to own ship are shown with numerals indicating the arc measuring the angle. In composite tables 5, 6, and 7, respectively, each indeterminate bearing, elevation, and traverse angle is symbolized and defined. For example, in figure 3, indeterminate bearing of the target from the N–S vertical plane to the normal-to-deck elevation plane measured in the deck plane is illustrated as the angle 10–9. In composite table 5, this angle is defined and symbolized ((***Bdy′***)). Indeterminate elevation of the target above the own ship deck plane, measured in the normal elevation plane, to the slant plane through the LOS and through the director elevation axis in the deck plane is illustrated as the angle 9–5. In composite table 6, this angle is defined and symbolized ((***Eds′***)). Indeterminate traverse of the target from the normal elevation plane to the LOS, measured in the slant plane through the LOS and through the director elevation axis in the deck plane is illustrated as the angle 5–1. In composite table 7, this angle is defined and symbolized ((***′Bsd***)).

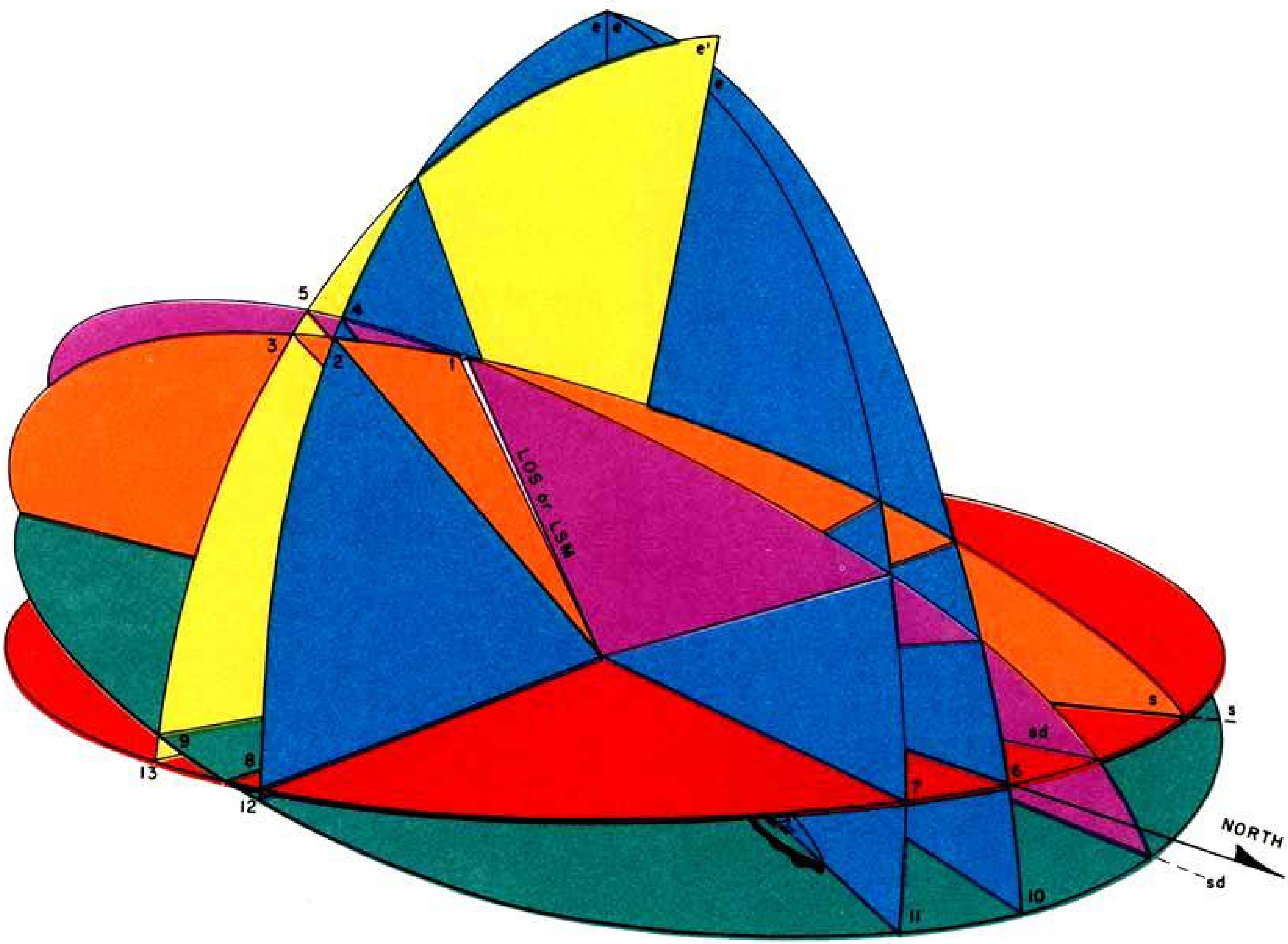

Figure 3—Indeterminate Angular Target and Missile Coordinates.

Table 5

			To vertical elevation plane	To normal-to-deck elevation plane
Indeterminate target bearing from own ship	In horizontal plane	From N–S vertical plane	6–8 ((*By*))	6–13 ((*By′*))
		From vertical plane through OSCL	7–8 ((*B*))	7–13 ((*B′*))
	In own ship deck plane	From N–S vertical plane	10–12 ((*Bdy*))	10–9 ((*Bdy′*))
		From vertical plane through OSCL	11–12 ((*Bd*))	11–9 ((*Bd′*))

Table 6

			To slant plane through LOS and through the director elevation axis in the	
			Horizontal plane	Own ship deck plane
Indeterminate target elevation from own ship	In vertical elevation plane	From horizontal plane	8–2 ((*E*))	8–4 ((*Es*))
		From own ship deck plane	12–2 ((*Ed*))	12–4 ((*Eds*))
	In normal-to-deck elevation plane	From horizontal plane	13–3 ((*E′*))	13–5 ((*Es′*))
		From own ship deck plane	9–3 ((*Ed′*))	9–5 ((*Eds*))

Table 7

			To LOS from	
			Vertical elevation plane	Normal-to-deck elevation plane
Indeterminate target traverse from own ship	In a slant plane through LOS and through the director elevation axis in the deck plane	Horizontal plane	2–1 ((*Bs*))	3–1 ((*′Bs*))
		Own ship deck plane	4–1 ((*Bsd*))	5–1 ((*′Bsd*))

Indeterminate bearing, elevation, and traverse angles expressing present missile position with respect to own ship may also be shown on figure 3, if the line of sight to the missile (LSM) is used as the sighting line instead of the line of sight (LOS). Each indeterminate missile coordinate is symbolized and defined in composite tables 8, 9, and 10. For example, in figure 3, indeterminate bearing of the missile from the N–S vertical plane to the normal-to-deck elevation plane, measured in the deck plane is illustrated as the angle 10–9. In composite table 8, this angle is defined and symbolized ((***Bdmy′***)). Indeterminate elevation of the missile above the own ship deck plane, measured in the normal elevation plane, to the slant plane through the LSM and through the director elevation axis in the deck plane is illustrated as the angle 9–5. In composite table 9, this angle is defined and symbolized ((***Edsm′***)). Indeterminate traverse of the missile, from the normal elevation plane to the LSM, measured in the slant plane through the LSM and through the director elevation axis in the deck plane is illustrated as the angle 5–1. In composite table 10, this angle is defined and symbolized ((***′Bsdm***)).

Table 8

			To vertical elevation plane	To normal-to-deck elevation plane
Indeterminate missile bearing from own ship	In horizontal plane	From N–S vertical plane	6–8 ((***Bmy***))	6–13 ((***Bmy′***))
		From vertical plane through MCL	7–8 ((***Bm***))	7–13 ((***Bm′***))
	In own ship deck plane	From N–S vertical plane	10–12 ((***Bdmy***))	10–9 ((***Bdmy′***))
		From vertical plane through MCL	11–12 ((***Bdm***))	11–9 ((***Bdm′***))

Table 9

			To slant plane through LSM and through the director elevation axis in the	
			Horizontal plane	Own ship deck plane
Indeterminate missile elevation from own ship	In vertical elevation plane	From horizontal plane	8–2 ((***Em***))	8–4 ((***Ems***))
		From own ship deck plane	12–2 ((***Edm***))	12–4 ((***Edsm***))
	In normal-to-deck elevation plane	From horizontal plane	13–3 ((***Em′***))	13–5 ((***Ems′***))
		From own ship deck plane	9–3 ((***Edm′***))	9–5 ((***Edsm′***))

Table 10

<table>
<tr><td rowspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2">To LSM from</td></tr>
<tr><td>Vertical elevation plane</td><td>Normal-to-deck elevation plane</td></tr>
<tr><td rowspan="2">Indeterminate missile traverse from own ship</td><td rowspan="2">In a slant plane through LSM and through the director elevation axis in the deck plane</td><td>Horizontal plane</td><td>2-1 ((Bsm))</td><td>3-1 (('Bsm))</td></tr>
<tr><td>Own ship deck plane</td><td>4-1 ((Bsdm))</td><td>5-1 (('Bsdm))</td></tr>
</table>

Target and Missile Ranges. To the target ranges from own ship described in volume 1, chapter 1, must be added missile ranges from own ship (see figure 4 and table 11), and target ranges from missile (see figure 5 and table 12). In symbolizing these ranges the basic range symbol, ***R,*** is used, together with the additional missible modifier, ***m.*** When ***m*** follows ***R,*** as in ***Rm,*** a missile range from own ship is indicated; when ***m*** precedes ***R,*** as in ***mR,*** a target range from missile is indicated.

In figure 4, ranges expressing present missile position with respect to own ship are shown with numerals indicating the distances. In composite table 11, each range quantity is symbolized and defined. For example, in figure 4, the projection of missile range from own ship in the horizontal plane by a vertical plane through the line of sight to the missile is illustrated as the distance 0–8. In composite table 11 this distance is defined and symbolized ***Rhm.***

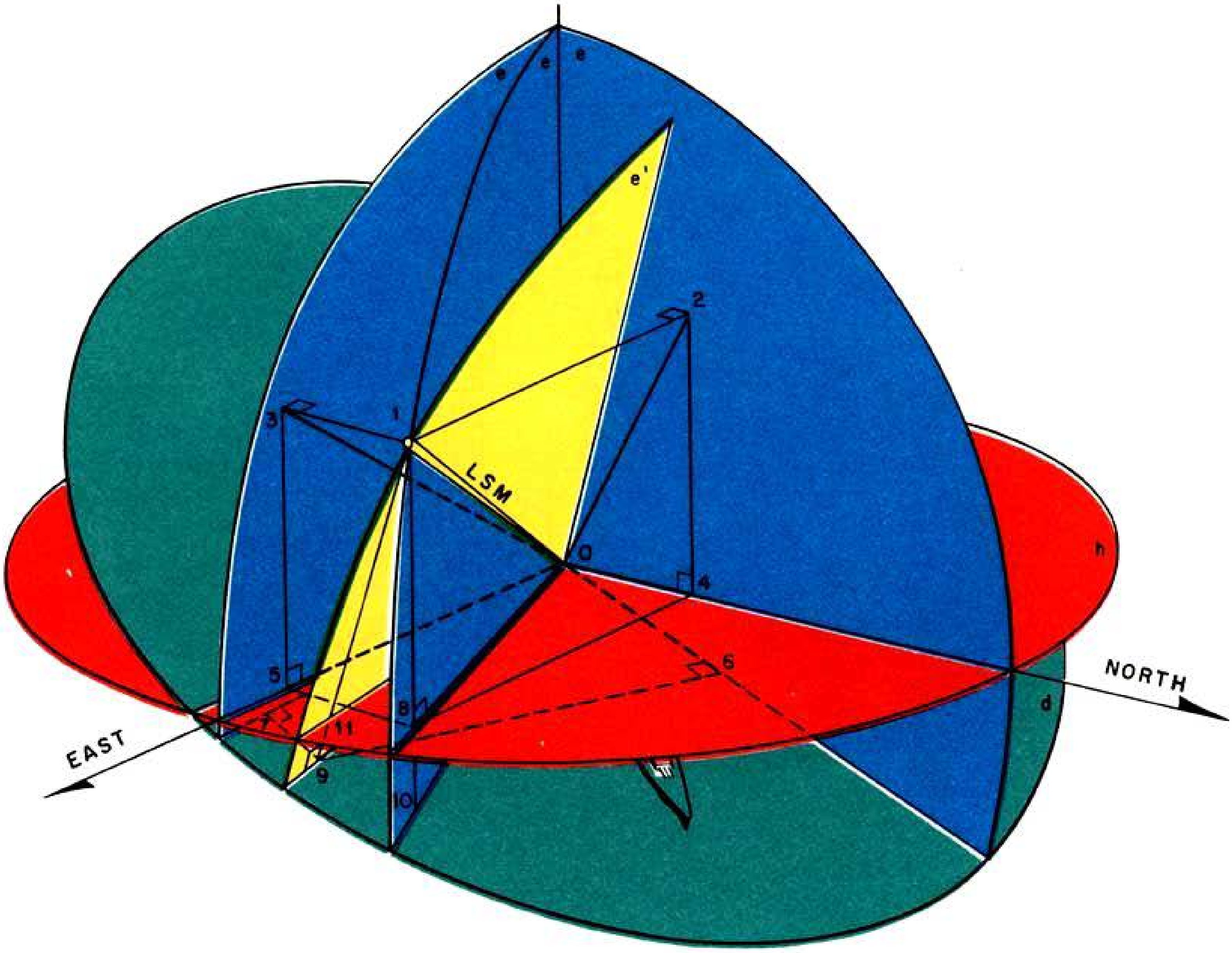

Figure 4—Missile Ranges and Missile Heights.

Table 11

					N–S Component	E–W Component
Missile range from own ship	Along LSM			***Rm*** 0–1	***Rmy*** 0–2	***Rmx*** 0–3
	Along intersection of	Vertical plane through LSM	And horizontal	***Rhm*** 0–8	***Rhmy*** 0–4	***Rhmx*** 0–5
		Normal-to-deck plane through LSM	And own ship deck	***Rdm*** 0–9	***Rdmy*** 0–6	***Rdmx*** 0–7

Missile height from own ship	In vertical plane through LSM	Above horizontal	***Rmv*** 8–1
		Above own ship deck	***Rdmv*** 10–1
	In normal-to-deck plane through LSM	Above horizontal	***Rmv′*** 11–1
		Above own ship deck	***Rdmv′*** 9–1

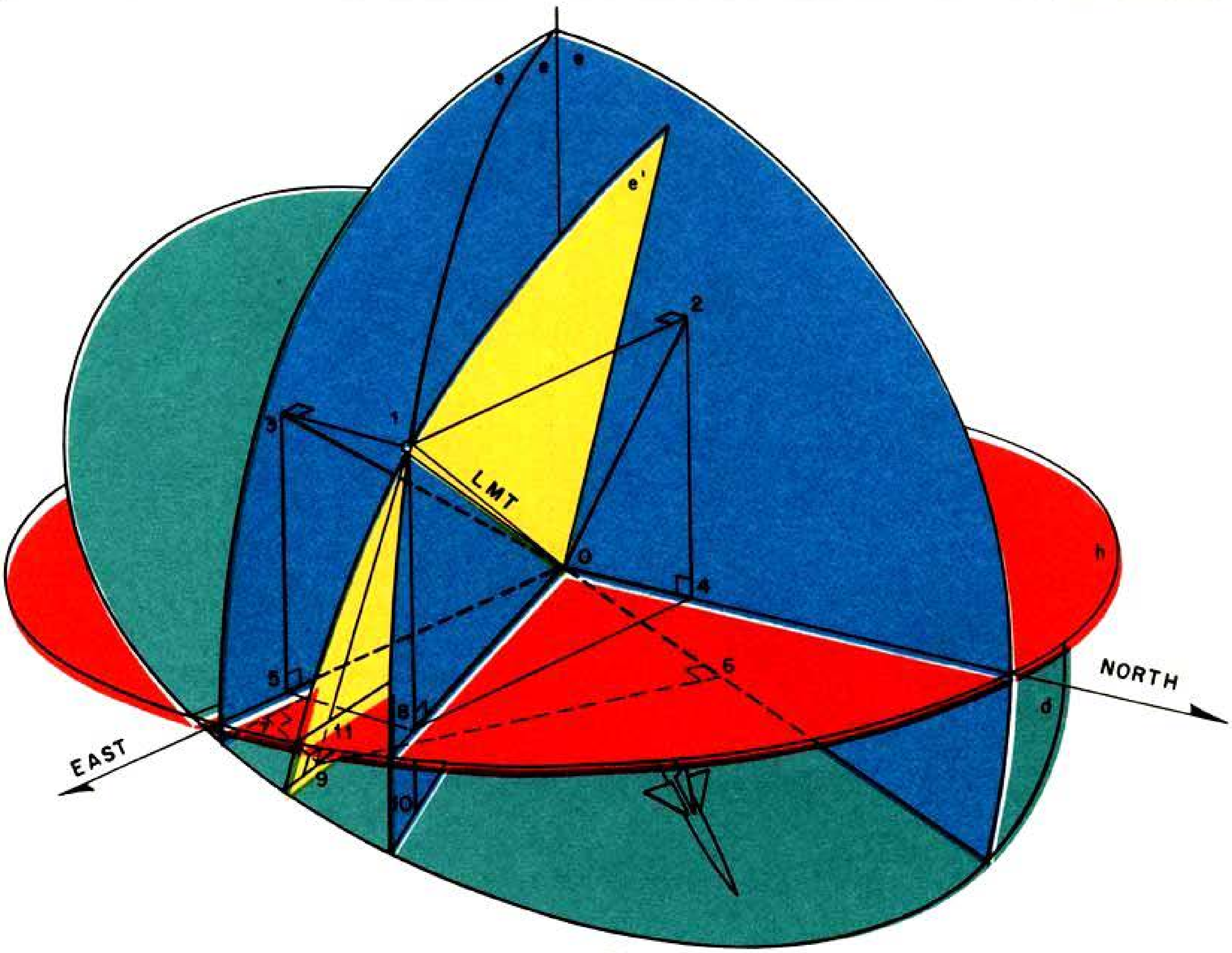

Figure 5—Target-from-Missile Ranges and Target-from-Missile Heights.

Table 12

					N–S Component	E–W Component
Target range from missile	Along LMT			***mR*** 0–1	***mRy*** 0–2	***mRx*** 0–3
	Along inter-section of	Vertical plane through LMT	And hori-zontal	***mRh*** 0–8	***mRhy*** 0–4	***mRhx*** 0–5
		Normal-to-missile deck plane through LMT	And missile deck	***mRd*** 0–9	***mRdy*** 0–6	***mRdx*** 0–7

Target height from missile	In vertical plane through LMT	Above horizontal	***mRv*** 8–1
		Above missile deck	***mRvd*** 10–1
	In normal-to-missile deck plane through LMT	Above horizontal	***mRv′*** 11–1
		Above missile deck	***mRvd′*** 9–1

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In figure 5, ranges expressing present target position with respect to missile are shown with numerals indicating the distances. In composite table 12, each range quantity is symbolized and defined. For example, in figure 5, the projection of target range from missile in the horizontal plane by a vertical plane through the missile line of sight is illustrated as the distance 0–8. In composite table 12, this distance is defined and symbolized ***mRh.***

Maneuvering Quantities

Generally, the quantities described and symbolized in this publication are those used in the solution of the launching phase of the problem. That is, the quantities are those required to solve the problem at some instant of launch.

For many attacks, a pre-launching phase is required in the solution of the problem. This phase involves the measurements and computations required when launching is delayed, because of target or own ship maneuvers or any other reason, and it is called the "maneuvering phase" of the problem.

The quantities required during the maneuvering phase are exactly the same as those required during the launching phase. Therefore, in most instances, the symbols used for maneuvering quantities are exactly the same as those used for launching quantities. In instances where it is necessary to distinguish between them, the symbols for maneuvering quantities are unchanged, while the corresponding launching quantities are symbolized by applying the numeral modifier ***1*** after the symbols for the maneuvering quantities. For example, horizontal target range from own ship is ordinarily symbolized ***Rh***. Therefore, this range during maneuvering also is symbolized ***Rh,*** but at launch ***Rh1.***

The numeral modifier ***1*** is applied to quantities during the launching phase only when a possibility of confusion between maneuvering and launching quantities exists. In instances where no confusion is possible, the numeral modifier is eliminated from the launching quantities.

Coordinate Transformation

Geometrical quantities closely associated with target and missile position values are quantities expressing:

1. Inclination of own ship deck and missile deck planes from the horizontal plane, and
2. Displacements between own ship reference point and radars, and corrections to measured radar values accounting for these displacements.

The planes and lines used to express these quantities are essentially the same as those used with target and missile position values.

Deck Inclination. The own ship deck inclination problem for missiles is complicated by the fact that level and cross-level angles now must be measured with respect to the line of sight to the missile as well as the line of sight, as in the antiaircraft problem, described in volume 1, chapter 1. In addition, means for measuring missile deck inclination must be provided.

OWN SHIP AND MISSILE LEVEL ANGLES. To the own ship level angles described in volume 1, chapter 1, must be added own ship level angles referred to the line of sight to the missile (see figure 1 and table 13), and missile level angles referred to the missile line of sight (see figure 2 and table 14). In symbolizing these level angles, the basic level angle symbol ***Ei*** is used together with the additional missile modifier ***m.*** When ***m*** follows ***Ei*** as in ***Eim,*** an own ship level angle referred to the line of sight to the missile is indicated; when ***m*** precedes ***Ei*** as in ***mEi,*** a missile level angle referred to the line of sight from missile to target is indicated.

In figure 1, own ship level angles expressing inclination of own ship deck plane with respect to the horizontal plane, referred to the line of sight to the missile, are shown with numerals indicating the arc measuring the angle. In composite table 13, each level angle is symbolized and defined. For example, in figure 1, level angle measured between the horizontal and own ship deck planes in the vertical plane through the line of sight to the missile is illustrated as the angle 5–11. In composite table 13, this angle is defined and symbolized ***Eim.***

Table 13

	In vertical plane through LSM	In normal-to-deck plane through LSM
Own ship level (angle between horizontal and own ship deck plane)	***Eim*** 5–11	***Eim′*** 6–8

Table 14

	In vertical plane through LMT	In normal-to-missile-deck plane through LMT	In vertical plane through MCL
Missile level (angle between horizontal and missile deck planes)	***mEi*** 5–11	***mEi′*** 6–8	***mEio*** 3–12

In figure 2, missile level angles expressing inclination of missile deck plane with respect to the horizontal plane, referred to the missile line of sight, are shown with numerals indicating the arc measuring angle. In composite table 14, each level angle is symbolized and defined. For example, in figure 2, level angle measured between the horizontal and missile deck planes in the vertical plane through the line of sight from missile to target is illustrated as the angle 5–11. In composite table 14, this angle is defined and symbolized ***mEi***.

Own Ship and Missile Cross-Level Angles. To the own ship cross-level angles described in volume 1, chapter 1, must be added own ship cross-level angles referred to the line of sight to the missile (see figure 1 and table 15), and missile cross-level angles referred to the line of sight from missile to target (see figure 2 and table 16). In symbolizing these cross-level angles, the basic cross-level angle symbol ***Z*** is used together with the additional missile modifier ***m***. When ***m*** follows ***Z*** as in ***Zm***, an own ship cross-level angle referred to the line of sight to the missile is indicated; when ***m*** precedes ***Z*** as in ***mZ***, a missile cross-level angle referred to the line of sight from missile to target is indicated.

Table 15

			And vertical plane through LSM	And normal-to-deck plane through LSM
Own ship cross-level (angle between vertical and normal-to-deck planes)	About intersection of	Horizontal plane	***Zm*** 5	***Zm′*** 6
		Own ship deck plane	***Zdm*** 11	***Zdm′*** 8

Rotation about LSM	***Zsm*** 14

In figure 1, own ship cross-level angles expressing inclination of the deck plane with respect to the horizontal plane, referred to the line of sight to the missile, are shown with numerals to indicate the axis about which the angle is measured. In composite table 15, each cross-level angle is symbolized and defined. For example, in figure 1, cross-level angle between the normal-to-deck plane through the line of sight to the missile and a vertical plane measured about an axis which is the intersection of the normal plane and the deck plane is illustrated as the angle measured about axis 8. In composite table 15, this angle is defined and symbolized ***Zdm'***.

In figure 2, missile cross-level angles expressing inclination of the missile deck plane with respect to the horizontal plane, referred to the line of sight from missile to target, are shown with numerals to indicate the axis about which the angle is measured. In composite table 16, each cross-level angle is symbolized and defined. For example, in figure 2, cross-level angle between the normal-to-missile-deck plane through the line of sight from missile to target and a vertical plane measured about an axis which is the intersection of the normal plane and the missile deck plane, is illustrated as the angle measured about axis 8. In composite table 16, this angle is defined and symbolized ***mZd'***.

Correction Quantities. When correction quantities used in converting from stable to unstable coordinates are computed approximately from the measured values of level and cross-level, they are symbolized as described in volume 1 under Symbol System. When the conversion is computed exactly, no correction quantities or symbols for them are required.

Static Director Parallax. All of the considerations relating to static director parallax described in volume 1, chapter 1, are carried over to the missile problem with the following amplification. It is found necessary to distinguish between radars associated with the target and radars associated with the missile. Target or tracking radar parallax is identical with the director parallax described in volume 1, chapter 1, and symbolized with the basic symbol ***Ps;*** missile or guidance director parallax is described in a similar way and symbolized by the basic symbol ***Pm***. The missile modifier, ***m***, indicates that a missile director is being considered. Where a single radar both tracks the target and guides the missile, no distinction is necessary, and the symbol ***Ps*** is used.

Table 16

			And vertical plane through LMT	And normal-to-missile-deck plane through LMT	And vertical plane through MCL
Missile cross-level (angle between vertical and normal-to-missile-deck planes)	About intersection of	Horizontal plane	***mZ*** 5	***mZ'*** 6	
		Missile deck plane	***mZd*** 11	***mZd'*** 8	***mZo*** 12

Rotation about LMT	***mZs*** 14

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Chapter 2

MOTION

The missile fire control problem may be divided into two primary phases, the launching phase, and the guidance phase. The launching phase is concerned with the directing of the missile from the launcher to a predicted point in space called the capture point, where the guidance devices of the missile fire control system begin to control the missile. The guidance phase begins at capture, and ends with target interception or missile sterilization.

The launching phase is completely analogous to the antiaircraft problem, as described in volume 1, chapters 1 through 5. The major difference is the replacement of target future position of the antiaircraft problem with missile capture position of the missile problem.

Motion quantities are used to compute the linear or angular offsets required to aim the launcher, resulting from relative motion between own ship and target during the time of flight of the missile. These offsets are combined with ballistic correction offsets to determine the total launcher offsets from the line of sight (LOS), or from the line of sight to the missile (LSM). Motion quantities also are used to offset the LSM from the line of fire during the launching phase, and from the LOS during the guidance phase.

The measurements of motion in naval missile fire control comprises the expression of:

1. Linear motion of own ship, missile, and target
2. Angular motion of the LOS or LSM
3. Motion between frames of reference
4. Courses, headings, and target angles

Linear Motion

Linear motion as described in volume 1, chapter 2, also applies to missile fire control, with certain additions and qualifications. To the linear displacement quantities described in volume 1, chapter 2 must be added the components of linear displacement of the target position at missile capture. These linear displacements are symbolized by applying the numeral modifier ***6,*** to the symbols for the same components of displacement resulting from total relative motion between own ship and target.

In figures 6 through 9, all the components of capture displacement, ***M6***, are illustrated since they are in the same directions as the components of total displacement, ***M***.

In composite tables 17 through 20, each capture displacement component is defined and symbolized. For example, in figure 6, the component measured perpendicular to the vertical plane through the line of sight is illustrated as the distance 0–2. In composite table 17, this displacement is defined and symbolized ***Mb6***.

Certain missile problems require the expression of total relative displacement of target relative to the missile, and its components. These linear displacements are measured either from own ship (in own ship reference frame) for use during the launching or guidance phases of the problem, or from the missile (in missile reference frame) for use during the guidance phase. All of these displacements are symbolized by prefixing the missile modifier, ***m,*** to the symbols for the same components of displacement resulting from total relative motion between own ship and target. Where there is danger of confusing components measured from the missile with those measured from own ship, the latter are enclosed in parentheses and terminated with the modifier ***o,*** indicating that the measurements are made in own ship reference frame, while the former are enclosed in parentheses and terminated with the modifier ***h,*** indicating that the measurements are made in the missile reference frame.

Note: ***o*** and ***h*** are quantity modifiers. (See appendix C).

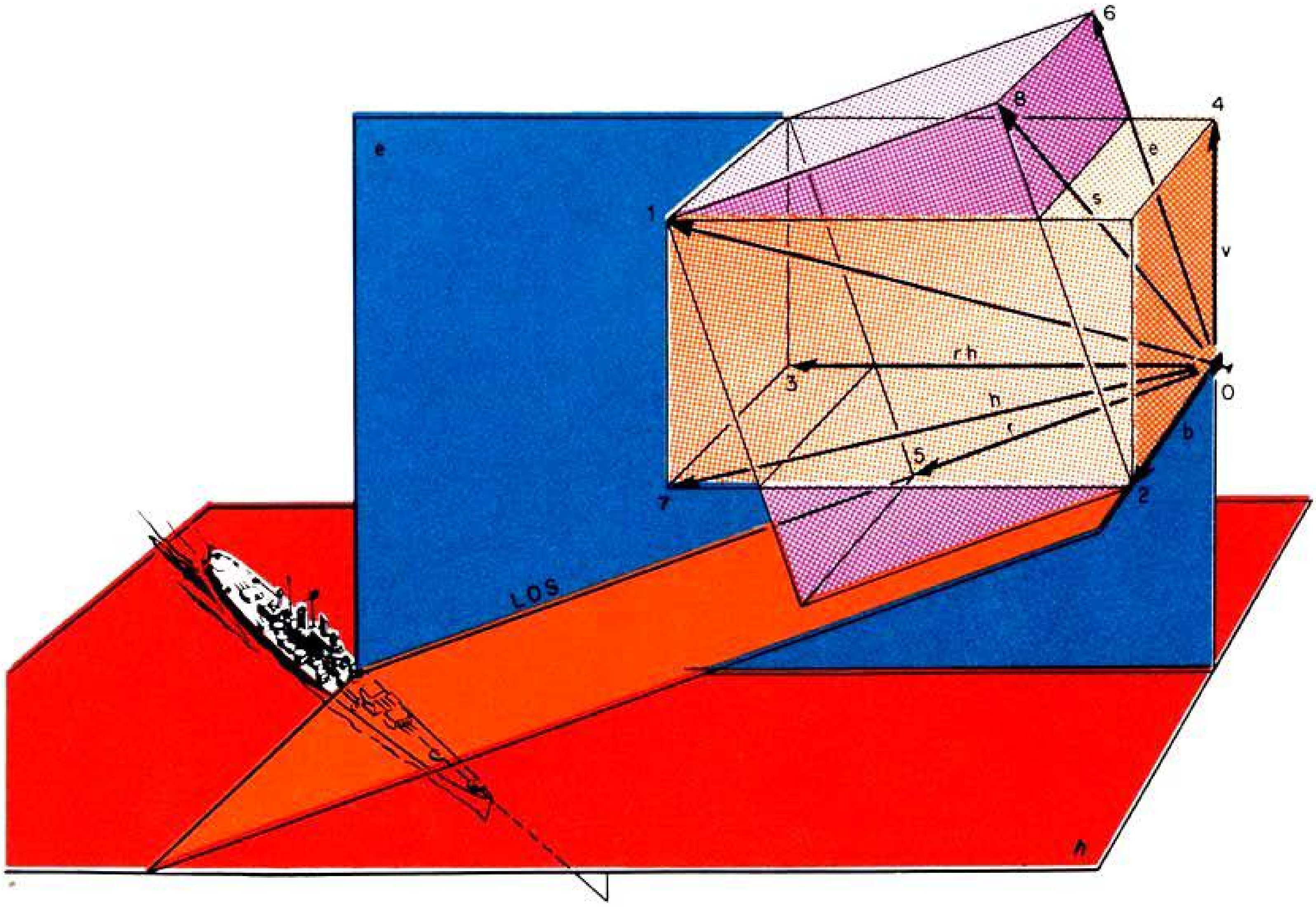

Figure 6— Capture Target Displacement About Line of Sight in Stable Coordinates.

Table 17

	Relative		Capture
Displacement during time of flight	***M***	0–1	***M6***
Displacement perpendicular to vertical plane through LOS	***Mb***	0–2	***Mb6***
Displacement in horizontal in vertical plane through LOS	***Mrh***	0–3	***Mrh6***
Displacement in vertical in vertical plane through LOS	***Mv***	0–4	***Mv6***
Displacement along LOS	***Mr***	0–5	***Mr6***
Displacement perpendicular to LOS in vertical plane through LOS	***Me***	0–6	***Me6***
Displacement in horizontal in vertical plane through course line	***Mh***	0–7	***Mh6***
Total displacement in plane perpendicular to LOS	***Ms***	0–8	***Ms6***

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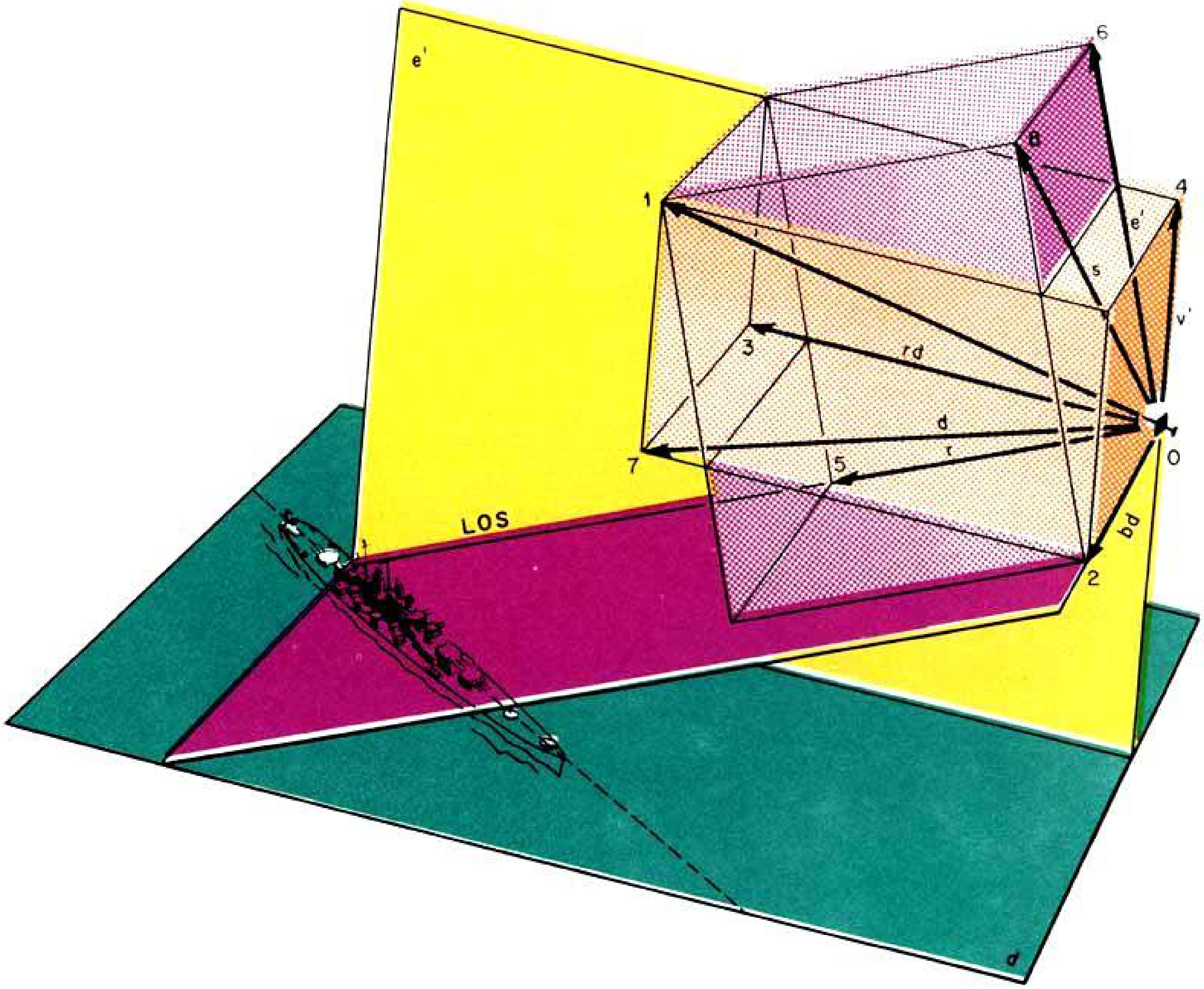

Figure 7—Capture Target Displacement About Line of Sight in Unstable Coordinates.

Table 18

	Relative		Capture
Displacement during time of flight	***M***	0-1	***M6***
Displacement perpendicular to normal plane through LOS	***Mbd***	0-2	***Mbd6***
Displacement in own ship deck in normal-to-deck plane through LOS	***Mrd***	0-3	***Mrd6***
Displacement along a line normal-to-deck to own ship deck	***Mv'***	0-4	***Mv6'***
Displacement along LOS	***Mr***	0-5	***Mr6***
Displacement perpendicular to LOS in normal-to-deck plane through LOS	***Me'***	0-6	***Me6'***
Displacement in own ship deck in normal-to-deck plane through course line	***Md***	0-7	***Md6***

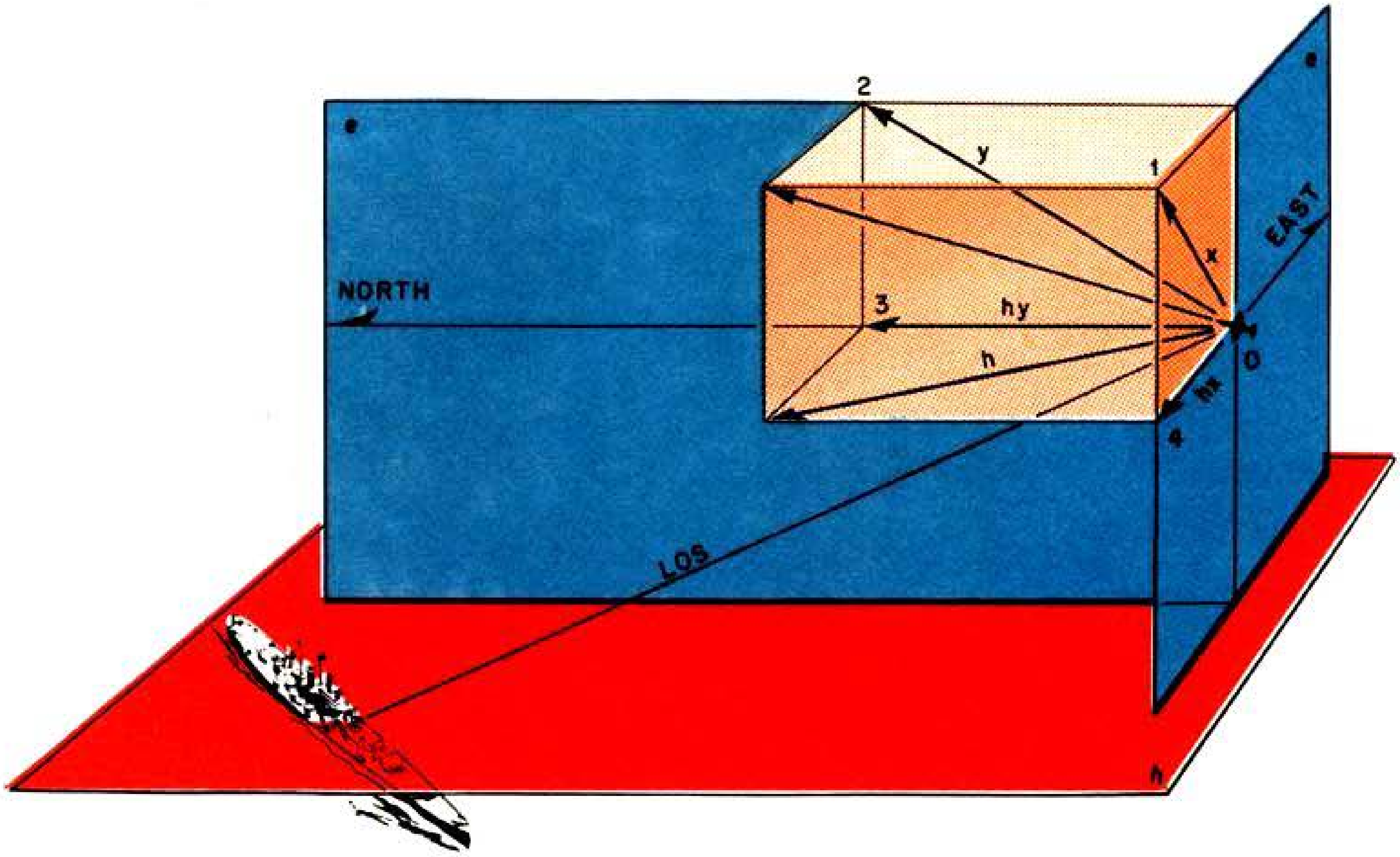

Figure 8—North-South and East-West Projections of Capture Target Displacement in Stable Coordinates.

Table 19

		Relative		Capture
Projection of displacement (*M*) in	N–S vertical plane	*My*	0–2	*My6*
	E–W vertical plane	*Mx*	0–1	*Mx6*
Projection of displacement (*Mh*) in	N–S vertical plane	*Mhy*	0–3	*Mhy6*
	E–W vertical plane	*Mhx*	0–4	*Mhx6*

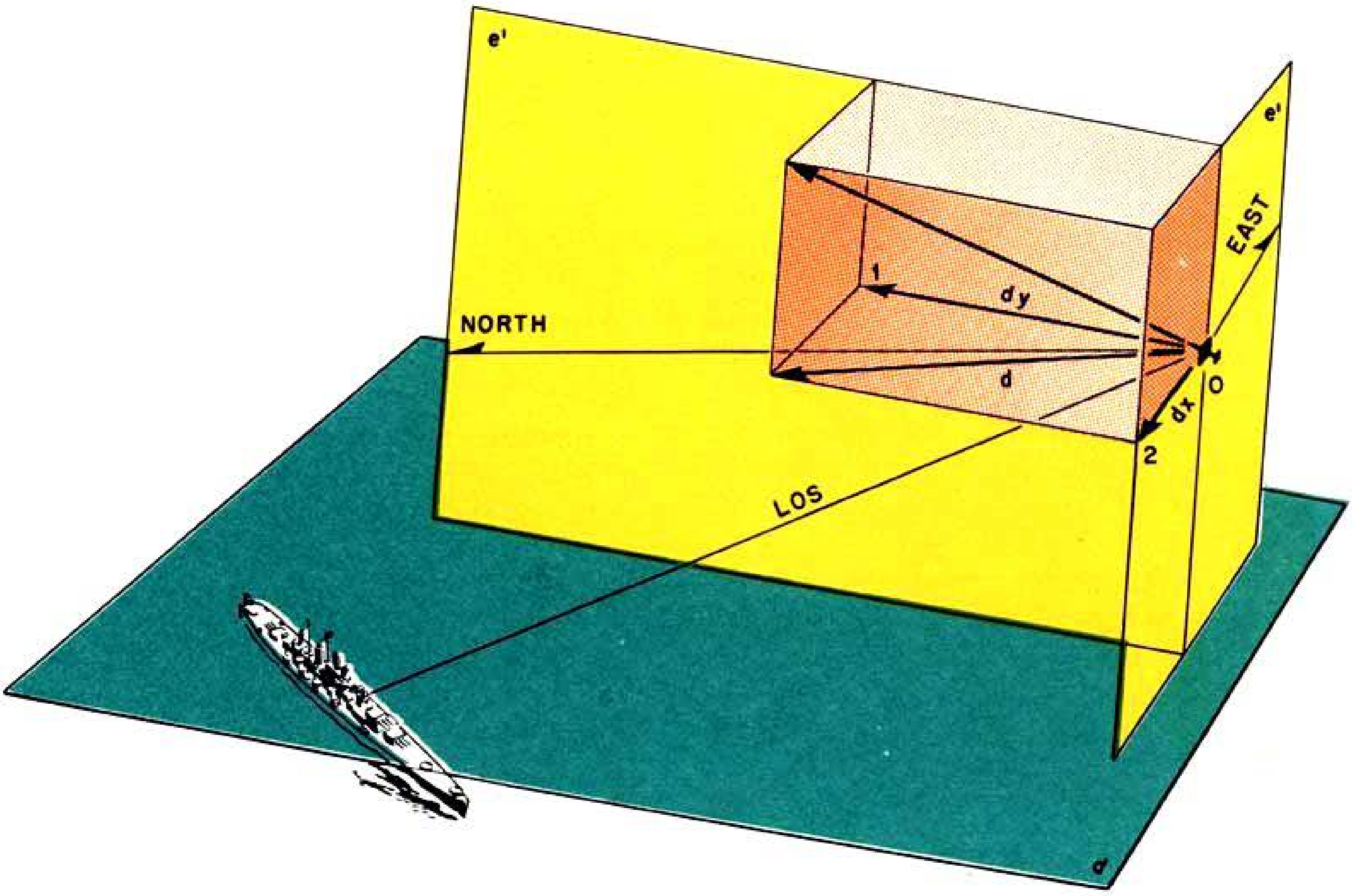

Figure 9—North-South and East-West Projections of Capture Target Displacement in Unstable Coordinates.

Table 20

		Relative	Capture
Projection of displacement ***(Md)*** in	N–S normal-to-deck plane	***Mdy*** 0–1	***Mdy6***
	E–W normal-to-deck plane	***Mdx*** 0–2	***Mdx6***

In figures 10 through 13, all the components of relative guidance displacement, ***mM,*** measured from own ship, are illustrated. In composite tables 21 through 24, each guidance displacement component is defined and symbolized.

For example, in figure 10, the vertical displacement component is illustrated as the distance 0–4. In composite table 21, this displacement is defined and symbolized (***mMv***)***o.***

The portions of the (***mM***)***o*** due to missile motion, (***mMm***)***o,*** and target motion, (***mMt***)***o,*** are formed in the same way that ***Mo*** and ***Mt*** are formed from ***M,*** as described in volume 1, chapter 2, and are also included in tables 21 through 24.

In addition, the displacement from the missile capture position to the aiming position, ***mM4,*** and the displacement from the missile capture position to the capture target position, ***mM6,*** and their components, are included in these tables.

In figures 12 through 15, all the components of relative guidance displacement, ***mM,*** measured from the missile, are illustrated. In composite tables 25 through 28, each guidance displacement component is defined and symbolized. For example, in figure 14, the vertical displacement component is illustrated as the distance 0–3. In composite table 25, this displacement is defined and symbolized (***mMv***)***h.***

The displacement ***mM*** and its components may be used in the launching phase of a missile problem, in which case they are relative constants of the capture problem; or in the guidance phase, where they become variables of the motion. In the latter case, the unmodified symbols given in the tables are used; in the former, the capture modifier, numeral ***6,*** is added as in the last columns of tables 21 through 24.

It will be seen that ***M6*** and ***mMt*** (at capture) are complementary parts of ***M,*** and ***Rm6*** and ***mMm*** (at capture) complementary parts of ***R2,*** corresponding to the launching and guidance portions of the target and missile trajectories, respectively. This relationship is illustrated in figure 16.

Special Linear Displacements. In certain analyses it is found convenient to treat small angles as vectors, that is, as linear displacements. The missile offset angle ***F*** (see chapter 5), when it is small, is an example for such an angle. Its arc on a circle of radius ***Rm6, F*** (in radians) x ***Rm6,*** is then approximately equal to its chord, tan ***F*** x ***Rm6,*** and total missile offset displacement ***Mf*** may be defined as: ***Mf*** = ***F*** x ***Rm6.*** The approximate displacement Mf is illustrated in figure 17, and its components are defined according to the method used for other displacements.

Correction Quantities. The same individual ballistic corrections to rates described in volume 1, chapter 2, are also applicable to the launching phase of the missile fire control problem. In some formulations of the missile problem, however, it is found necessary to correct linear displacements, rather than rates, for the various ballistic factors. Also, some ballistic factors, such as launcher rotational and translational velocities, which can be ignored in the antiaircraft problem, are no longer negligible, and must be corrected for, in the missile problem. Modifiers for adjusting displacements or rates are:

b	Superelevation or drift
g	Dead time
p	Launcher parallax
pm	Guidance radar parallax
ps	Director parallax
r	Launcher rotational velocity
t	Launcher translational velocity
w	Wind

For example, the correction to aiming displacement in horizontal range, ***Mrh4,*** for the effect of launcher rotational velocity is ***r***(***Mrh4***), and for the effect of dead time, ***g***(***Mrh4***). The correction to ***Mrh4*** for both of these factors is ***rg***(***Mrh4***).

Frames of Reference. To the frames of reference described in volume 1, chapter 2, must now be added the frame rigidly attached to the missile, denoted by the modifier ***h,*** following the quantity in parentheses. Thus, to express target from missile range rate in the missile frame, ***DmM,*** is enclosed in parentheses and followed by quantity modifier ***h,*** forming symbol (***DmM***)***h.***

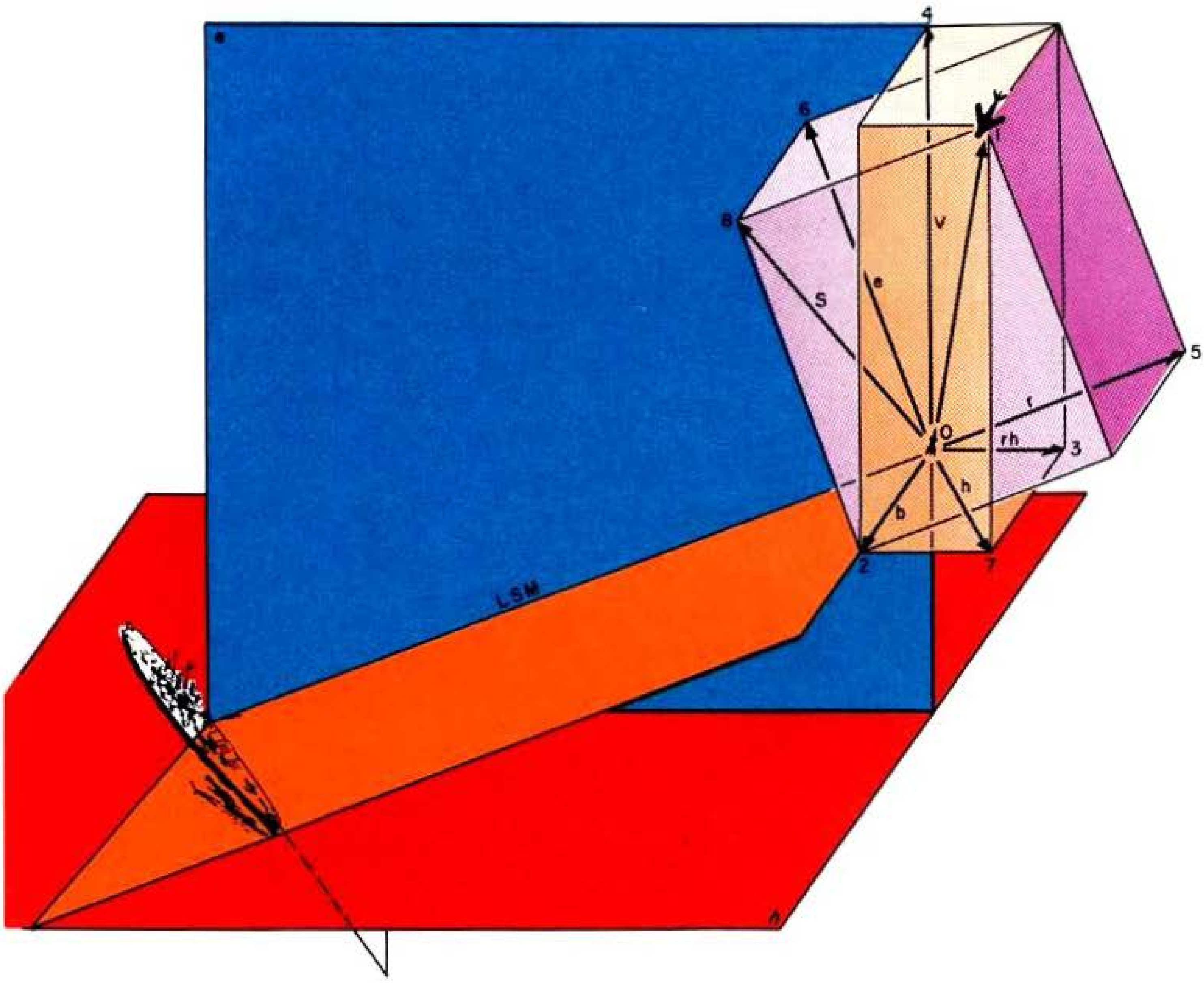

Figure 10—Relative Missile Displacement About Line of Sight to Missile in Stable Coordinates.

Table 21

	Relative Guidance	Missile	Target	To Aiming Position	Capture
Displacement at capture or thereafter	0—1 **(mM)o**	**(mMm)o**	**(mMt)o**	**mM4**	**mM6**
Displacement perpendicular to to vertical plane through LSM	0—2 **mMb**	**mMbm**	**mMbt**	**mMb4**	**mMb6**
Displacement in horizontal in vertical plane through LSM	0—3 **(mMrh)o**	**(mMrhm)o**	**(mMrht)o**	**mMrh4**	**mMrh6**
Displacement in vertical in vertical plane through LSM	0—4 **(mMv)o**	**(mMvm)o**	**(mMvt)o**	**mMv4**	**mMv6**
Displacement along LSM	0—5 **(mMr)**	**(mMrm)**	**(mMrt)**	**mMr4**	**mMr6**
Displacement perpendicular to LSM in vertical plane through LSM	0—6 **mMe**	**mMem**	**mMe**	**mMe4**	**mMe6**
Displacement in horizontal in vertical plane through missile course line	0—7 **(mMh)o**	**(mMhm)o**	**(mMht)o**	**mMh4**	**mMh6**
Total displacement in plane perpendicular to LSM	0—8 **mMs**	**mMsm**	**mMst**	**mMs4**	**mMs6**

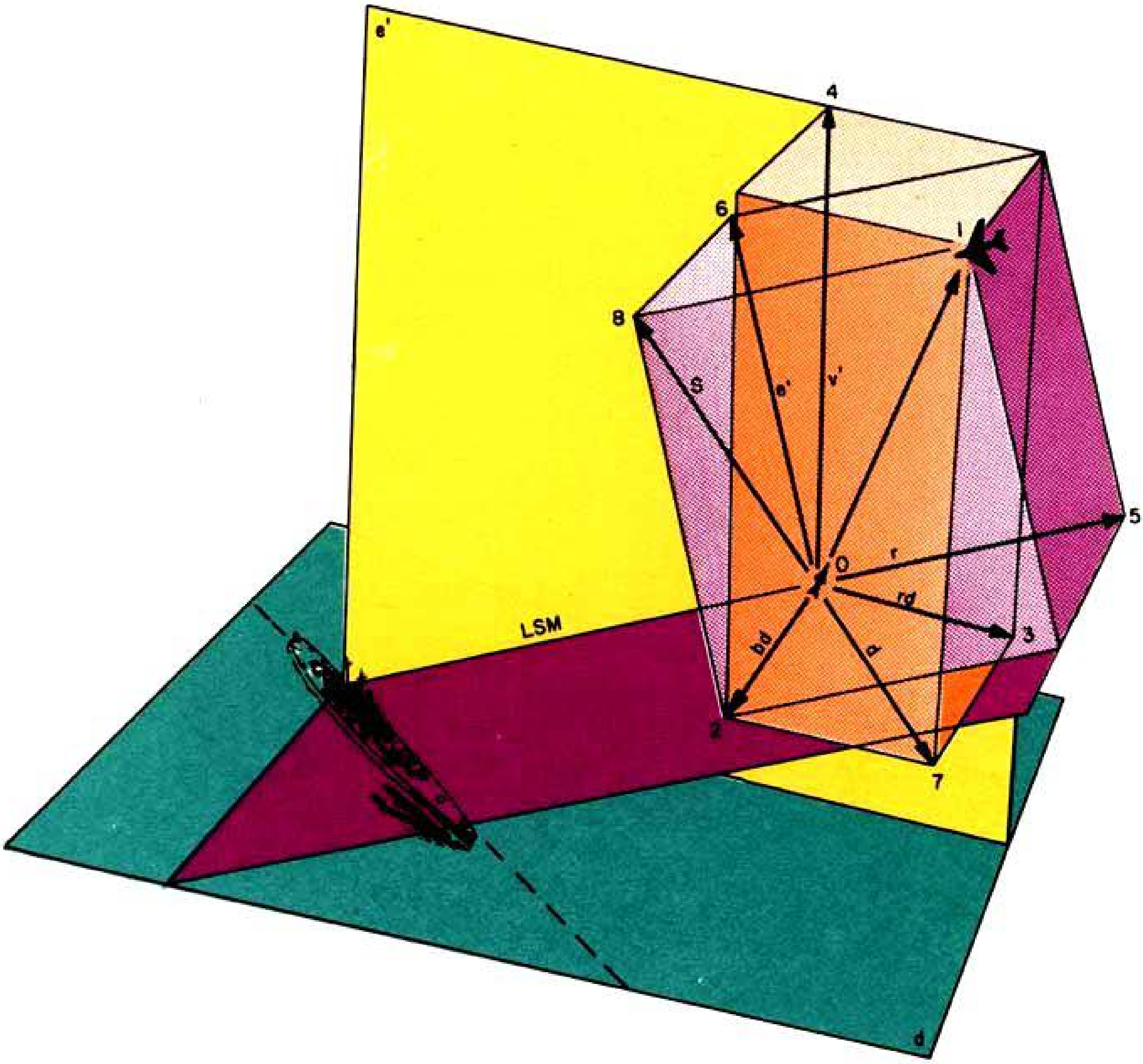

Figure 11—Relative Missile Displacement About Line of Sight to Missile in Unstable Coordinates.

Table 22

	Relative Guidance	Missile	Target	To Aiming Position	Capture
Displacement at capture or thereafter	*(mM)o*	*(mMm)o*	*(mMt)o*	*mM4*	*mM6*
Displacement perpendicular to normal-to-missile-deck plane through LSM	*mMbd*	*mMbdm*	*mMbdt*	*mMbd4*	*mMbd6*
Displacement in own ship deck in normal-to-deck plane through LSM	*(mMrd)o*	*(mMrdm)o*	*(mMrdt)o*	*mMrd4*	*mMrd6*
Displacement along a line normal to own ship deck	*(mMv')o*	*(mMvm')o*	*(mMvt')o*	*mMv4'*	*mMv6'*
Displacement along LSM	*mMr*	*mMrm*	*mMrt*	*mMr4*	*mMr6*
Displacement perpendicular to LSM in normal-to-missile-deck plane through LSM	*mMe'*	*mMem'*	*mMet'*	*mMe4'*	*mMe6'*
Displacement in own ship deck in normal-to-deck plane through missile course line	*(mMd)o*	*(mMdm)o*	*(mMdt)o*	*mMd4*	*mMd6*

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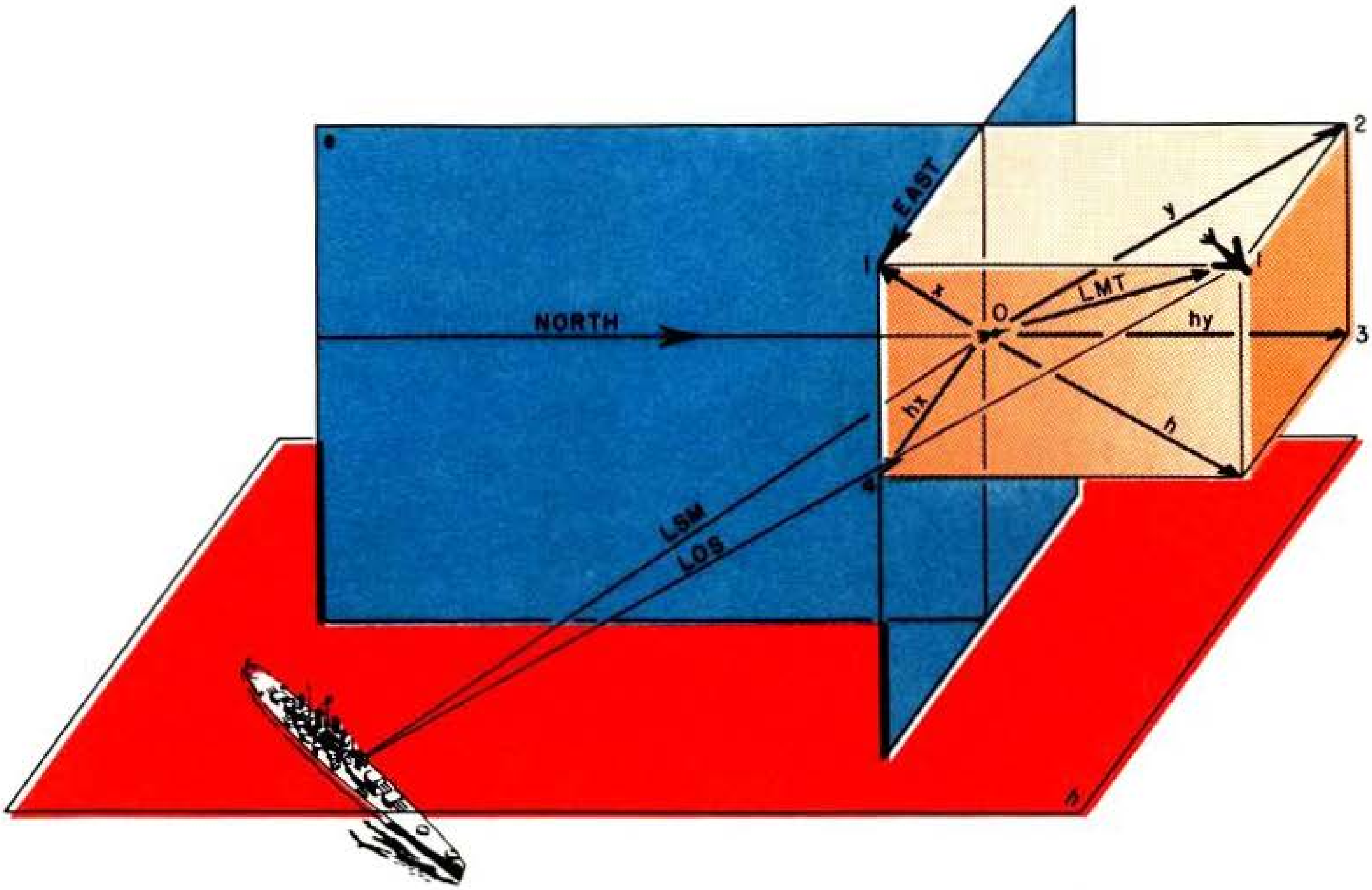

Figure 12—North-South and East-West Projections of Relative Missile Displacement in Stable Coordinates.

Table 23

		Relative Guidance	Missile	Target	To Aiming Position	Capture
Projection of displacement ***(mM)o*** in	N–S vertical plane	0–2 ***(mMy)o***	***(mMym)o***	***(mMyt)o***	***mMy4***	***mMy6***
	E–W vertical plane	0–1 ***(mMx)o***	***(mMxm)o***	***(mMxt)o***	***mMx4***	***mMx6***
Projection of displacement ***(mMh)o*** in	N–S vertical plane	0–3 ***(mMhy)o***	***(mMhym)o***	***(mMhyt)o***	***mMhy4***	***mMhy6***
	E–W vertical plane	0–4 ***(mMhx)o***	***(mMhxm)o***	***(mMhxt)o***	***mMhx4***	***mMhx6***

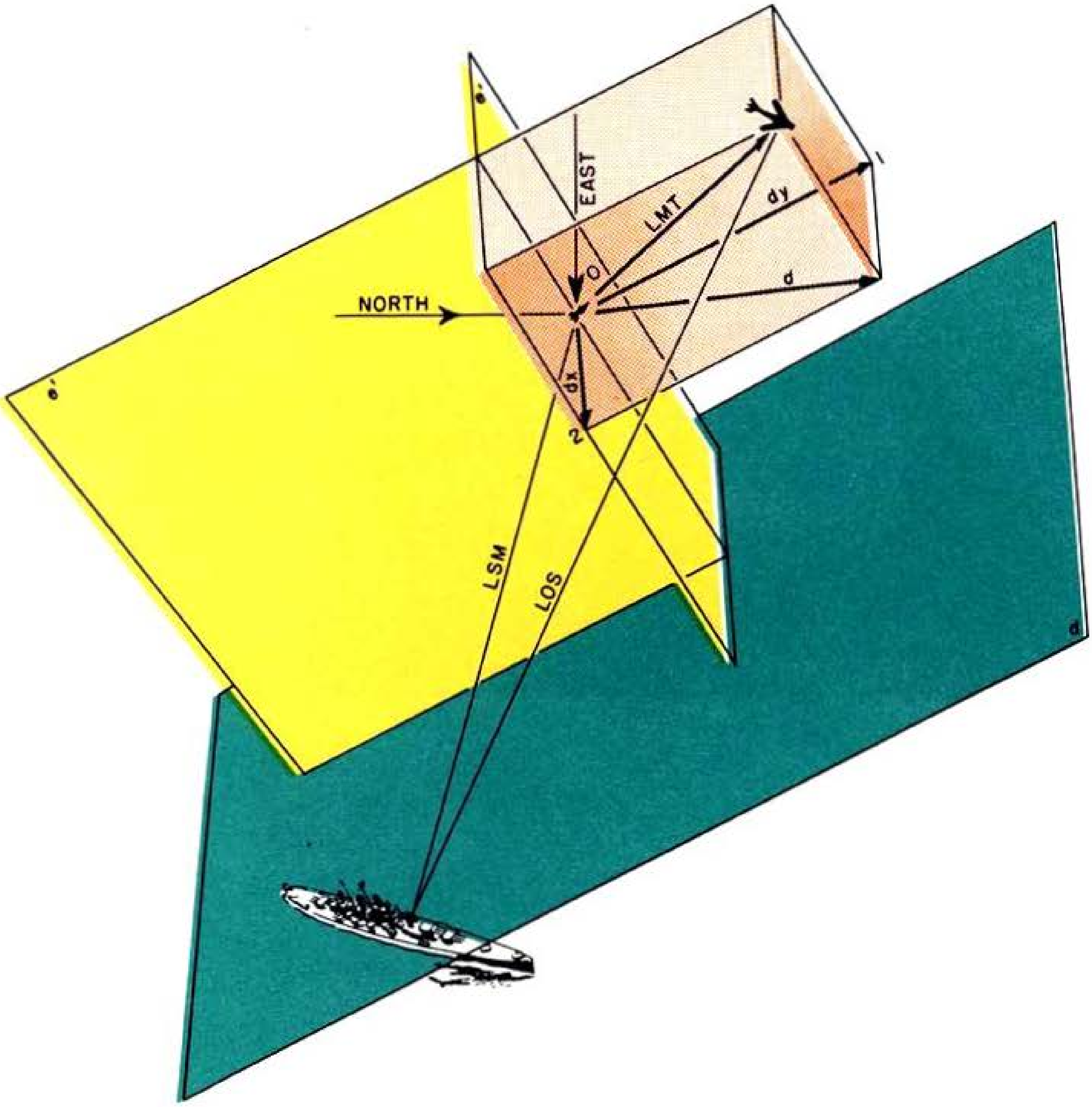

Figure 13—North-South and East-West Projections of Relative Missile Displacement in Unstable Coordinates.

Table 24

		Relative Guidance	Missile	Target	To Aiming Position	Capture
Projection of displacement $(mMd)o$ in	N–S normal-to-deck plane	0–1 $(mMdy)o$	$(mMdym)o$	$(mMdyt)o$	$mMdy4$	$mMdy6$
	E–W normal-to-deck plane	0–2 $(mMdx)o$	$(mMdxm)o$	$(mMdxt)o$	$mMdx4$	$mMdx6$

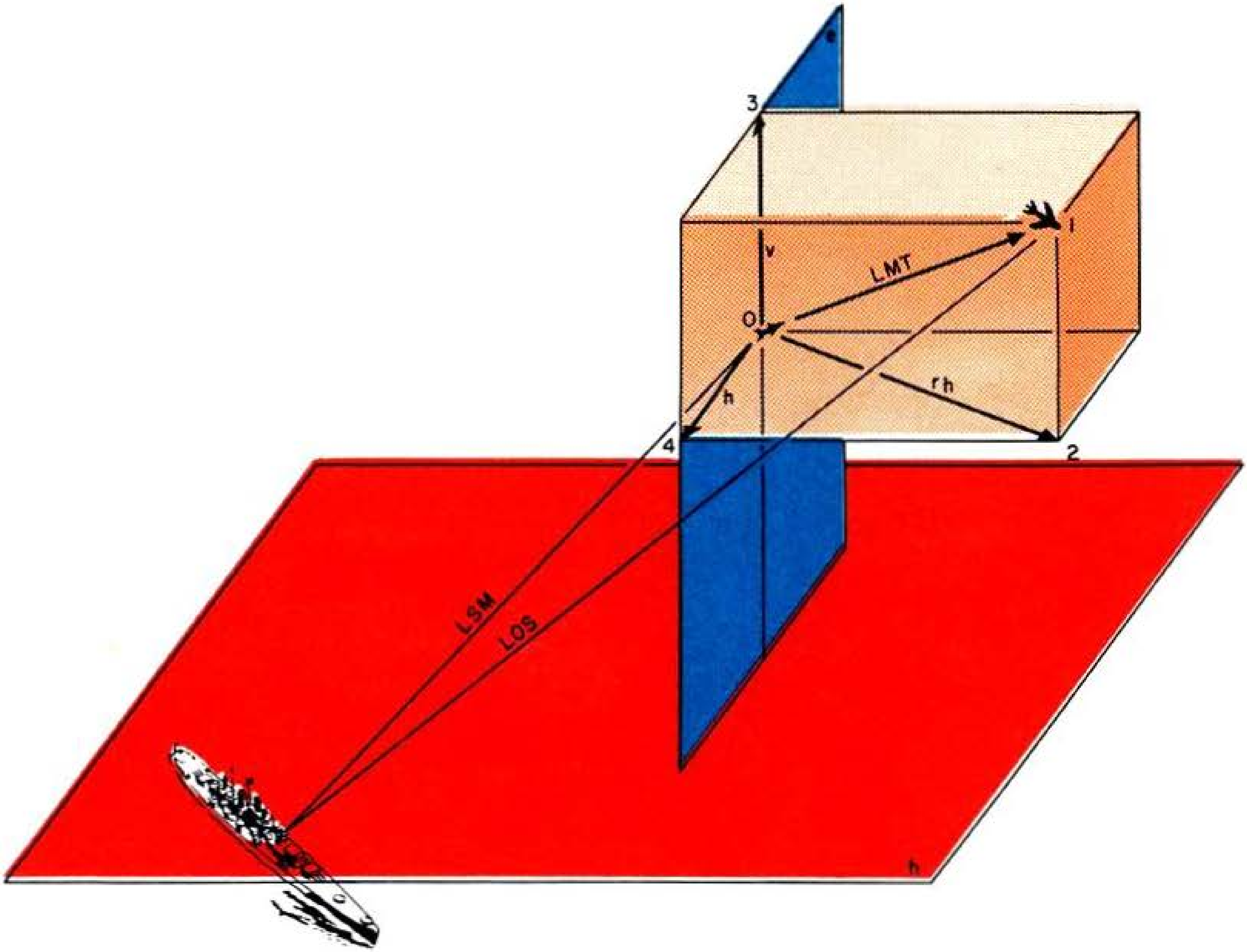

Figure 14—Relative Missile Displacement About Missile Line of Sight in Stable Coordinates.

Table 25

	Relative Guidance	Missile	Target
Displacement at capture or thereafter	$(mM)h$ 0–1	$(mMm)h$	$(mMt)h$
Displacement in horizontal in vertical plane through LMT	$(mMrh)h$ 0–2	$(mMrhm)h$	$(mMrht)h$
Displacement in vertical in vertical plane through LMT	$(mMv)h$ 0–3	$(mMvm)h$	$(mMvt)h$
Displacement in horizontal in vertical plane through missile course line	$(mMh)h$ 0–4	$(mMhm)h$	$(mMht)h$

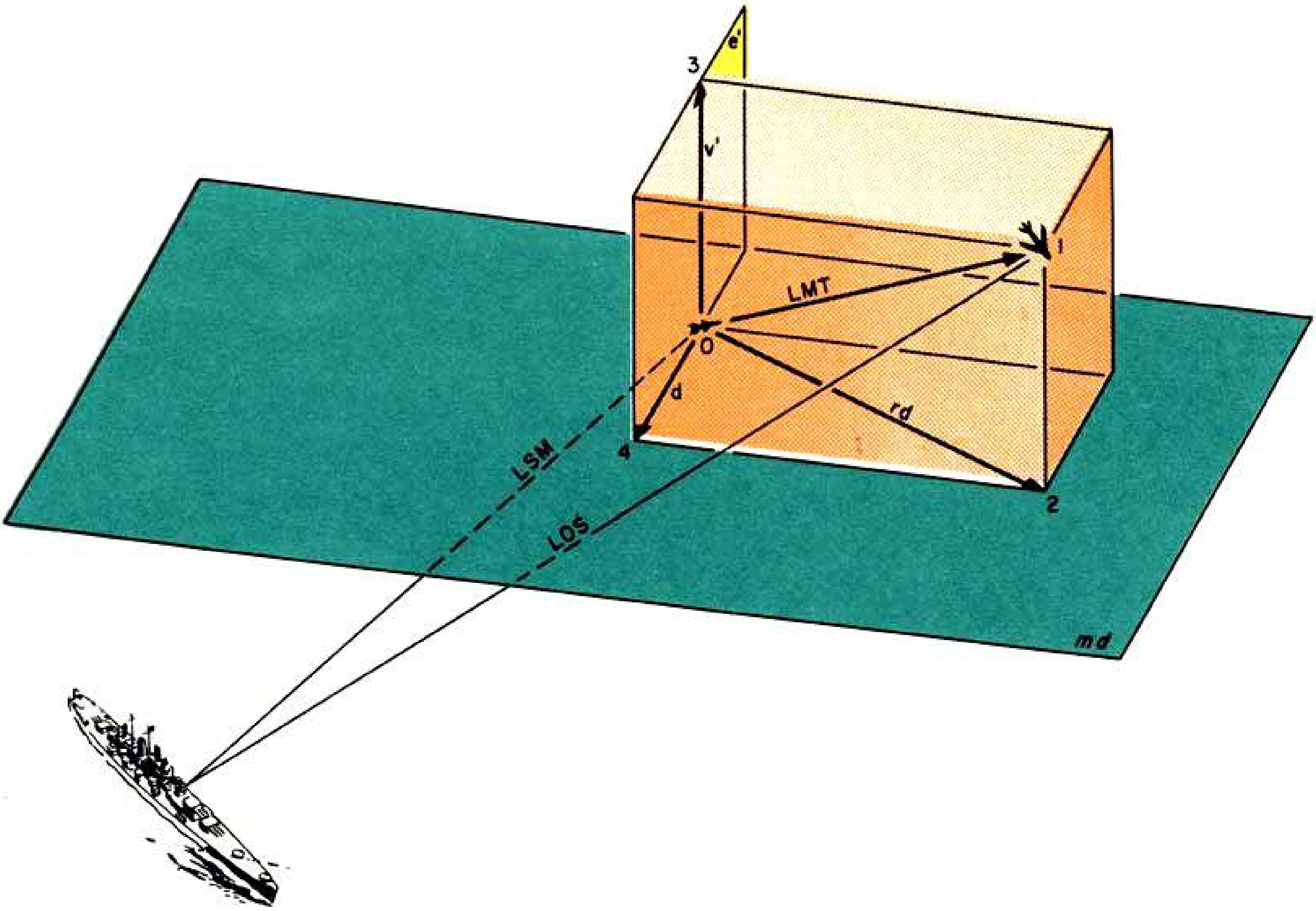

Figure 15—Relative Missile Displacement About Missile Line of Sight in Unstable Coordinates.

Table 26

	Relative Guidance	Missile	Target
Displacement at capture or thereafter	$(mM)h^{0-1}$	$(mMm)h$	$(mMt)h$
Displacement in missile deck in normal plane through LMT	$(mMrd)h^{0-2}$	$(mMrdm)h$	$(mMrdt)h$
Displacement along a line normal to missile deck	$(mMv')h^{0-3}$	$(mMvm')h$	$(mMvt')h$
Displacement in missile deck in normal plane through missile course line	$(mMd)h^{0-4}$	$(mMdm)h$	$(mMdt)h$

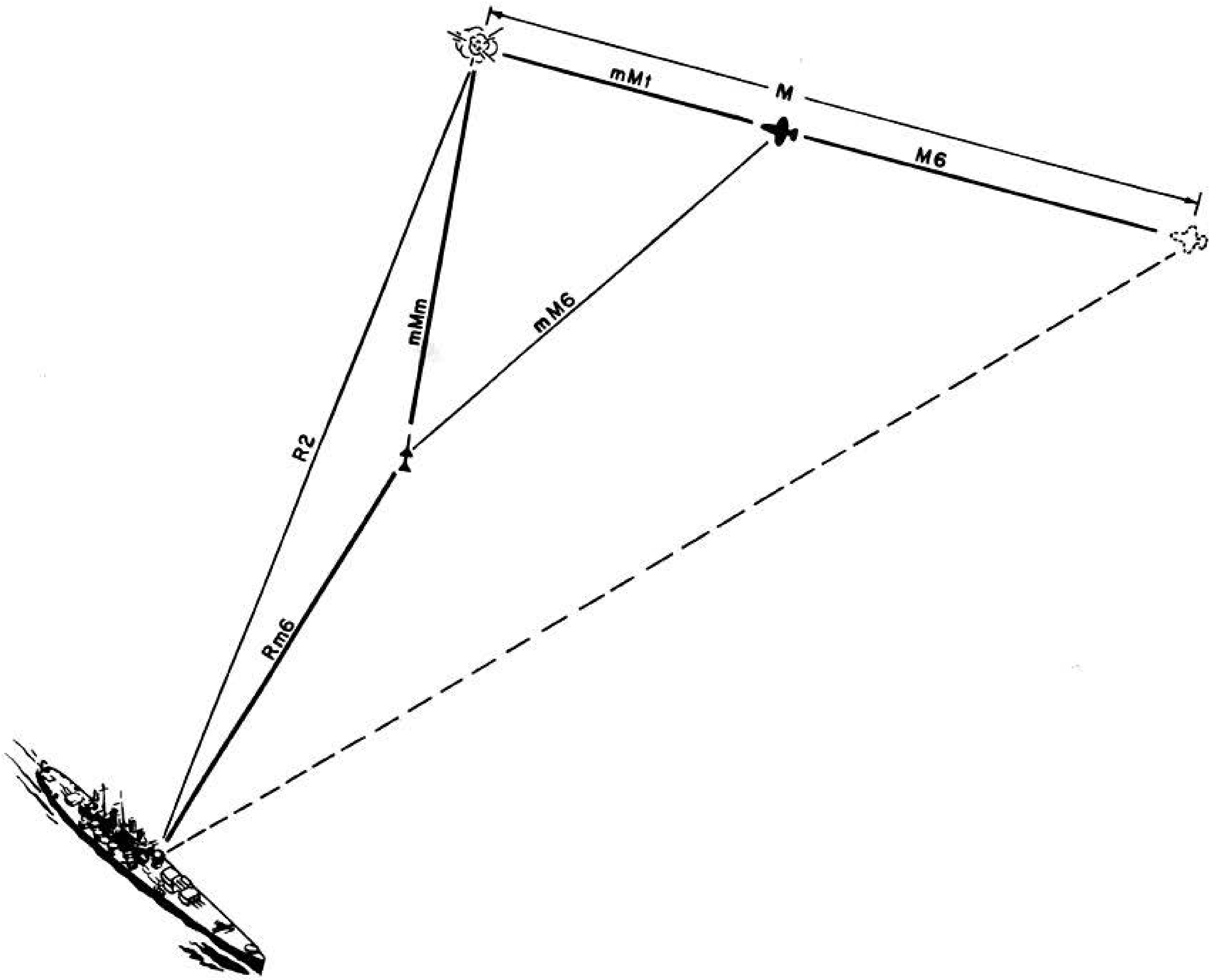

Figure 16—Relation Between Target and Missile Relative Displacements and Ranges.

Table 27

		Relative Guidance	Missile	Target
Projection of displacement $(mM)h$ in	N–S vertical plane	$(mMy)h$ 0–2	$(mMym)h$	$(mMyt)h$
	E–W vertical plane	$(mMx)h$ 0–1	$(mMxm)h$	$(mMxt)h$
Projection of displacement $(mMh)h$ in	N–S vertical plane	$(mMhy)h$ 0–3	$(mMhym)h$	$(mMhyt)h$
	E–W vertical plane	$(mMhx)h$ 0–4	$(mMhxm)h$	$(mMhxt)h$

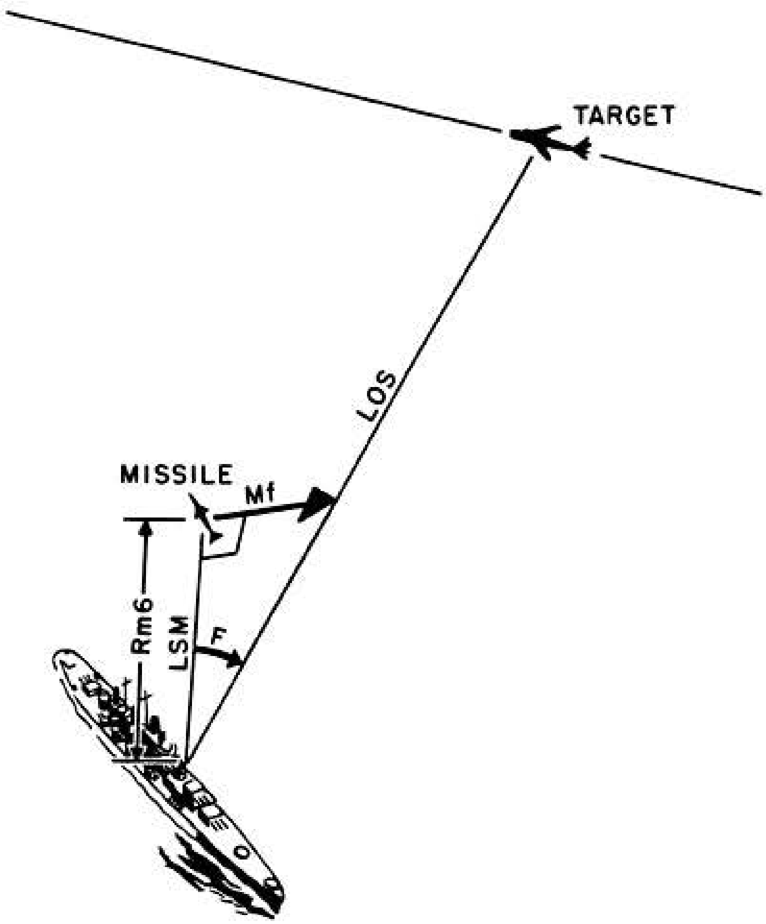

Figure 17—Missile Offset Displacement.

Table 28

		Relative Guidance	Missile	Target
Projection of displacement $(mMd)h$ in	N–S normal-to-missile-deck plane	0-1 $(mMdy)h$	$(mMdym)h$	$(mMdyt)h$
	E–W normal-to-missile-deck plane	0-2 $(mMdx)h$	$(mMdxm)h$	$(mMdxt)h$

Angular Motion

Angular motion as described in volume 1, chapter 2, also applies to missile fire control. It is only necessary to add the missile modifier, ***m***, to any basic symbol, to refer a quantity to the line of sight to the missile (LSM) instead of the line of sight (LOS).

Thus, for example, the angular elevation rate of the LSM is ***DEm***, and its angular bearing rate is ***DBM***.

In the case of the angular displacements ***A*** and ***S***, the corresponding missile angles, ***Am*** and ***Sm***, are defined for the line to the capture target position, instead of the line to the future target position.

Motion Between Frames of Reference

Motions between own ship frame, missile frame, earth frame, and inertial frame are used to transform own ship, missile, and target motions between these frames. Angular rates of motion in naval missile fire control can be considered in the following categories:

1. Motion of own ship frame with respect to the earth frame
2. Motion of missile frame with respect to the earth frame
3. Motion of missile frame with respect to the own ship frame
4. Motion of the earth frame with respect to the inertial frame
5. Motion of own ship frame with respect to the inertial frame
6. Motion of missile frame with respect to the inertial frame.

Motion between two frames requires the expression of the total translation rate of one frame with respect to the other, with useful components of this total translation rate, and the expression of the total rotation rate of one frame with respect to the other, with useful components of this total rotation rate.

Motion of Missile Frame With Respect to Earth Frame. The description of the motion of the missile frame with respect to the earth frame is similar to that of own ship frame with respect to the earth frame, contained in volume 1, chapter 2. It is only necessary to replace characteristic own ship quantities with corresponding missile quantities. Thus, the total translation rate of own ship frame with respect to the earth frame, (***DMo***)***k***, is replaced by (***DmMm***)***k***, the total translation rate of the missile frame with respect to the earth frame. Similarly, the total rotation rate of own ship frame with respect to the earth frame, ***DI***, is replaced by ***DmI***, the total rotation rate of the missile frame with respect to the earth frame. Useful components of ***DmI*** are obtained in the same way as components of ***DI***, as described in volume 1, chapter 2. Components of ***DmI*** are: ***DmZo***, ***DmEio***, and ***DCm***; or ***DmZ***, ***DmEi'***, ***DmBy***, and ***DCm***.

Motion of Missile Frame With Respect to Own Ship Frame. The translatlon rate of the missile frame with respect to own ship frame is simply expressed by combining the translation rates, relative to the earth frame, of the missile frame and of own ship frame. The rotation rate of the missile frame relative to own ship frame is one of the quantities that are minimized in optimum missile trajectories, and frequently is negligible. However, the orientation of the missile frame relative to own ship frame is of considerable importance in the missile problem. This orientation is simply expressed by combining the orientations, relative to the earth frame, of the missile frame and of own ship frame, as described under Coordinate Transformation, in chapter 1 of this volume and chapter 1 of volume 1.

Motion of Earth Frame With Respect to Inertial Frame. This motion is discribed in volume 1, chapter 2.

Motion of Own Ship and Missile Frames With Respect to Inertial Frame. Motion between own ship frame, or the missile frame, and the inertial frame is expressed by combining the motion of own ship frame, or the missile frame, with respect to the earth frame, with the motion of the earth frame relative to the inertial frame.

Missile Velocity

The class of quantities expressing missile velocities is indicated by the symbol ***U***. Missile velocities are measured as missile air speed or as average missile velocity to the future target position, or to the missile capture position.

The basic missile velocity quantity (represented by basic symbol ***U***) is the air speed of the missile with respect to the air mass, during the time of the missile's potency. Since this velocity varies, in general, ***U*** is given a nominal value, the average missile velocity from capture to burn out. In existing missiles, this velocity is independent of the reference frame used for the measurement.

To express the average missile velocities from launch to the future target position, and to the missile capture position, numeral modifiers are applied to the basic symbol ***U***. Numeral modifire ***2*** is used for average velocity to the future target position, forming symbol ***U2***, and ***6*** is used for missile capture position, forming symbol ***U6***.

The average missile velocity to the missile capture position multiplied by the capture time of flight equals missile capture range. That is, $U6 \times T6 = Rm6$. Similarly, $U2 \times T2 = R2$. The values of the average missile velocities to the future target position and to the missile capture position depend on the reference frame used by the fire control system, as described in volume 1, chapter 2.

Time

The description of time given in volume 1, chapter 2 applies to the missile problem as well, with certain additions and modifications.

To the time of flight ***T2*** must be added the time of flight to the missile capture position, ***T6***.

A new time quantity, director busy time, symbolized ***Tt***, is defined as the predicted time, measured from the present, for a missile director to complete its present assignment. That is, the time during which a director will be occupied with a given target or targets, hence the modifier ***t***.

The quantity ***T5***, fuze setting time in the antiaircraft problem, becomes fuze arming time in the missile problem.

Dead time, symbolized ***Tg***, is redefined, in the missile problem, as the time for which computed quantities must be modified when launching is delayed.

Courses, Headings, and Target Angles (Figure 18)

The description of courses, headings, and target angles in volume 1, chapter 2 also apply to the missile problem, with certain additions.

To courses ***Co*** and ***Ct*** is now added missile course ***Cm***, the angle between the N–S vertical plane, and the vertical plane through the missile speed vector (referred to the frame used by the fire control system), measured in the horizontal plane clockwise from north. The missile analog of basic course ***C*** is ***mC***, the angle between the N–S vertical plane and the vertical plane through the speed vector of the target relative to the missile (referred to the frame used by the fire control system), measured in the horizontal plane clockwise from north.

Similarly, to headings ***Cqo*** and ***Cqt*** is now added missile heading ***Cqm***, the angle between the N–S vertical plane and the vertical plane through the missile centerline, measured in the horizontal plane clockwise from north.

The missile analog of target angle ***Bot*** is ***Bmt***, the angle from the vertical plane through the target speed vector (referred to the frame used by the fire control system) to the vertical plane through the missile line of sight, measured in the horizontal plane clockwise from the target speed vector.

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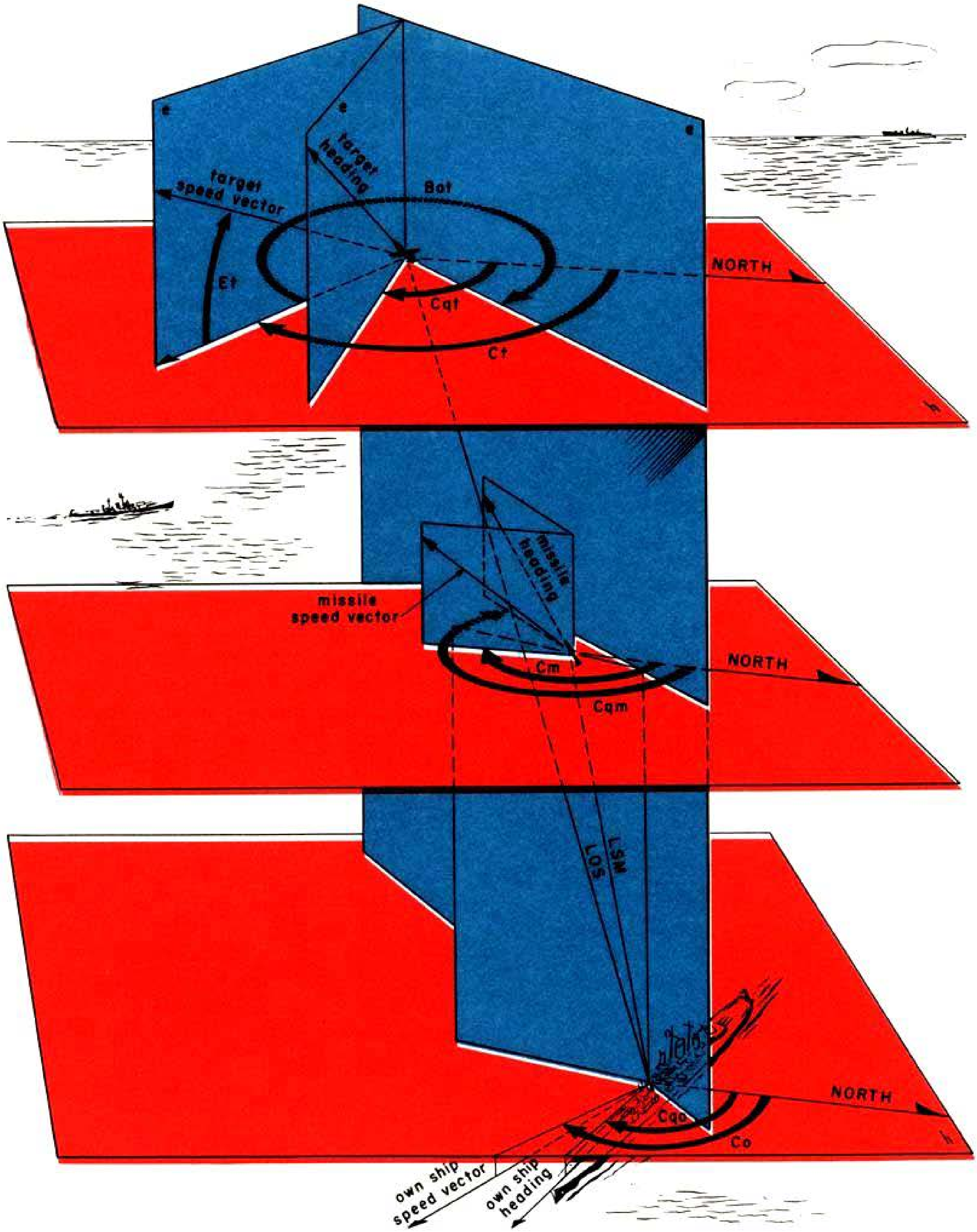

Figure 18—Courses, Headings, and Target and Missile Angles.

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Chapter 3

WIND

Wind values used for the launching phase of the missile problem, that is, to compute corrections to prediction quantities to account for the effect of wind on the missile during the boost period, are the same as those described in volume 1, chapter 3. Wind values used during the guidance phase, that is, to compute corrections to the missile trajectory during the remainder of the time of flight, are described in this chapter. The types of wind measured in determining these corrections are:

1. True wind—measure of air mass movement with respect to the earth. This rate is measured or computed by the missile.

2. Missile wind—resulting from motion of the missile over the earth. Its value, measured or computed by the missile, is equal and opposite to the missile speed relative to the earth.

3. Apparent missile wind—resultant of the vector addition of missile wind speed and true wind speed. This is the total wind acting to blow the missile off its course, and is the actual wind value measured aboard the missile.

Reference planes used for measuring missile wind quantities are:

1. Horizontal plane
2. Missile deck plane

Reference lines used are:

1. Missile centerline
2. N–S line
3. Missile line of sight
4. Missile velocity vector

The classes of wind quantities used are:

1. Wind bearings
2. Wind courses
3. Wind rates

Wind Bearings and Courses

The descriptions of missile wind bearings and courses are analogous to those contained in chapter 3, with the following changes to account for the replacement of own ship by the missile as the source of wind measurements and computations. Missile wind bearings and courses are measured in either the horizontal or missile deck planes. Bearings are measured from either the missile centerline or the N–S line, and to either the missile line of sight or the missile velocity vector (instead of the line of fire).

Wind bearings. The basic true wind bearing symbol is Bw, but the modifiers are applied now as follows:

MODIFIER	MEASURED
d ------	In missile deck
y ------	From north
s -------	To missile line of sight
g ------	To missile velocity vector
' -------	To normal plane

Missile wind bearings are expressed by terminating the symbol for the same true wind bearing with modifier ***m*** (instead of ***o*** for own ship).

Apparent missile wind bearings are expressed by prefixing the symbol for the same apparent (own ship) wind bearing with modifier ***m.***

In figure 19, all angles expressing bearings of true wind, missile wind, and apparent missile wind are shown with numerals indicating the arc measuring each bearing angle, where possible. In composite table 29, each bearing angle is symbolized and defined. For example, in figure 19, missile and true wind bearings in the horizontal plane, from the N–S vertical plane to the vertical plane through the direction from which the wind is blowing, are illustrated as the angles 1–5 and 1–2, respectively. Apparent missile wind bearing is arbitrary, since it depends on the relative magnitudes of missile and true wind speeds, and is therefore not shown on the figure. In composite table 29, these angles are defined and symbolized as:

1. ***Bwym*** (missile wind)
2. ***Bwy*** (true wind)
3. ***mBwya*** (apparent missile wind)

Table 29

				From N–S vertical plane	From vertical plane through MCL
Wind Bearing	To vertical plane through direction from which wind is blowing clockwise	In horizontal plane	Missile wind	1–3 ***Bwym***	
			True wind	1–2 ***Bwy***	3–2 ***Bw***
			Apparent missile wind	***mBwya***	***mBwa***
		In missile deck plane	Missile wind	14–13 ***Bwdym***	
			True wind	14–15 ***Bwdy***	13–15 ***Bwd***
			Apparent missile wind	***mBwdya***	***mBwda***

				To vertical plane through LMT	To normal-to-missile-deck plane through LMT	To vertical plane through MVV	To normal-to-missile-deck plane through MVV
Wind-Bearing	From vertical plane through direction from which wind is blowing clockwise	In horizontal plane	Missile wind	3–7 ***Bwsm***	3–8 ***Bwsm'***	3–5 ***Bwgm***	3–6 ***Bwgm'***
			True wind	2–7 ***Bws***	2–8 ***Bws'***	2–5 ***Bwg***	2–6 ***Bwg'***
			Apparent missile wind	***mBwsa***	***mBwsa'***	***mBwga***	***mBwga'***
		In missile deck plane	Missile wind	13–10 ***Bwdsm***	13–9 ***Bwdsm'***	13–12 ***Bwdgm***	13–11 ***Bwdgm'***
			True wind	15–10 ***Bwds***	15–9 ***Bwds'***	15–12 ***Bwdg***	15–11 ***Bwdg'***
			Apparent missile wind	***mBwdsa***	***mBwdsa'***	***mBwdga***	***mBwdga'***

Wind Courses. The basic true wind course symbol is ***Cw***, and missile modifiers are applied as described in the previous paragraph.

In figure 19, all angles expressing courses of true wind, missile wind, and apparent missile wind are shown with numerals indicating the arc measuring each course angle, where possible. In composite table 30, each course angle is symbolized and defined. For example, in figure 19, missile and true wind courses in the horizontal plane, from the N-S vertical plane to the vertical plane through the direction toward which the wind is blowing, are illustrated as the angles 1–3 (actually its supplement, since this

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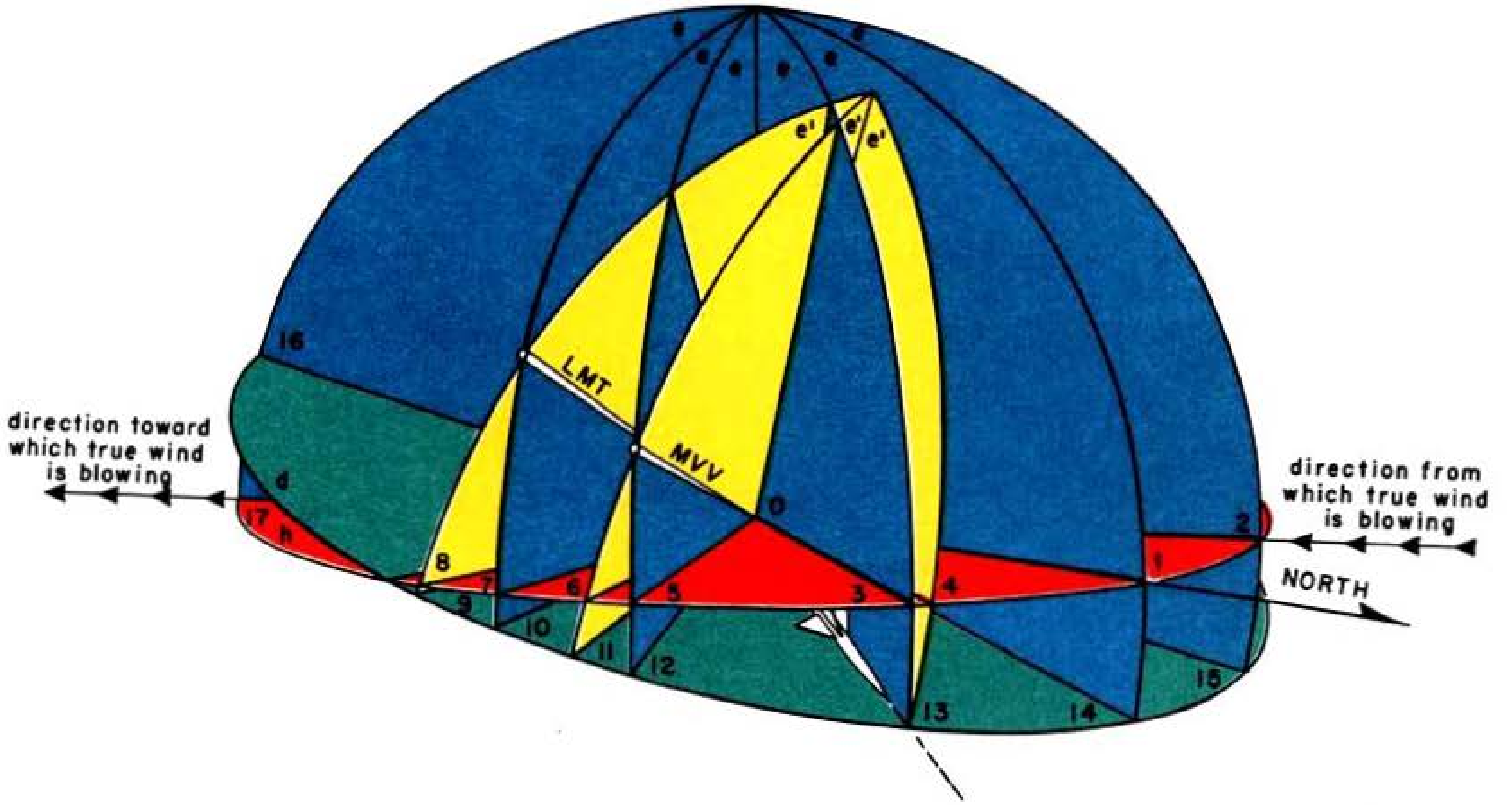

Figure 19—Missile Wind Bearings and Courses.

Table 30

				Missile wind	True wind	Apparent missile wind
Wind Course	From N–S vertical plane	To vertical plane through direction to which wind is blowing measured clockwise in	Horizontal plane	1–3 ***Cwm***	1–17 ***Cw***	***mCwa***
			Missile deck plane	14–13 ***Cwdm***	14–13 ***Cwd***	***mCwda***

angle is hidden in the figure) and 1–17, respectively. Apparent missile wind course is arbitrary, since it depends on the relative magnitudes of missile and true wind speeds, and therefore is not shown on the figure. In composite table 30, these angles are defined and symbolized as:

1. ***Cwm*** (missile wind)
2. ***Cw*** (true wind)
3. ***mCwa*** (apparent missile wind)

Wind Rates

The description of missile wind rates is analogous to that in volume 1, chapter 3, with following changes to account for the replacement of own ship by the missile as the source of wind measurements and computations. Missile wind rates are measured in either the horizontal or missile deck planes, from either the missile centerline or the N–S line, and to either the missile line of sight or the missile

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velocity vector (instead of the line of fire). The basic true wind rate symbol is ***W***, but the modifiers are applied now as follows:

MODIFIER	COMPONENT
bd	In missile deck, perpendicular to normal-to-deck plane through missile velocity vector
d	In missile deck, in normal-to-deck plane through course line
e	Perpendicular to missile velocity vector, in vertical plane through missile velocity vector
e′	Perpendicular to missile velocity vector, in normal-to-deck plane through missile velocity vector
g	Total, perpendicular to missile velocity vector
h	In horizontal, in vertical plane through course line
r	In range, along missile velocity vector
rd	In missile deck range, in normal-to-deck plane through missile velocity vector
rh	In horizontal range, in vertical plane through missile velocity vector
v	In vertical range, in vertical plane through missile velocity vector
v′	In normal range, in normal-to-missile-deck plane through missile velocity vector

Missile wind rates are expressed by terminating the symbol for the same true wind rate with modifier ***m*** (instead of ***o*** for own ship).

Apparent missile wind rates are expressed by prefixing the symbol for the same apparent (own ship) wind rate with modifier ***m***.

Figures 20 through 23 show all missile wind rates measured about the missile velocity vector. In general, to express these rates measured about the missile line of sight, the symbol for the same rate measured about the missile velocity vector is terminated with modifier ***s***, as described in volume 1, chapter 3. Figure 20 shows wind rate components measured in stable coordinates, figure 21 wind rate components measured in unstable coordinates, figure 22 stable wind rate components in the N–S and E–W directions, and figure 23 unstable wind rate components in the N–S and E–W directions. In composite tables (31, 32, 33, 34), each missile wind rate quantity, is defined and symbolized. For example, in figure 20, wind rates measured along the missile velocity vector are illustrated as the vector 0–5. In composite table 31, these wind rates are defined and symbolized as:

1. ***Wr*** (true wind)
2. ***Wrm*** (missile wind)
3. ***mWra*** (apparent missile wind)

If the missile line of sight (LMT) replaces the missile velocity vector (MVV), wind rates measured along the missile line of sight also are illustrated as the vector 0–5. From table 31, these rates are defined and symbolized as:

1. ***Wrs*** (true wind)
2. ***Wrms*** (missile wind)
3. ***mWras*** (apparent missile wind)

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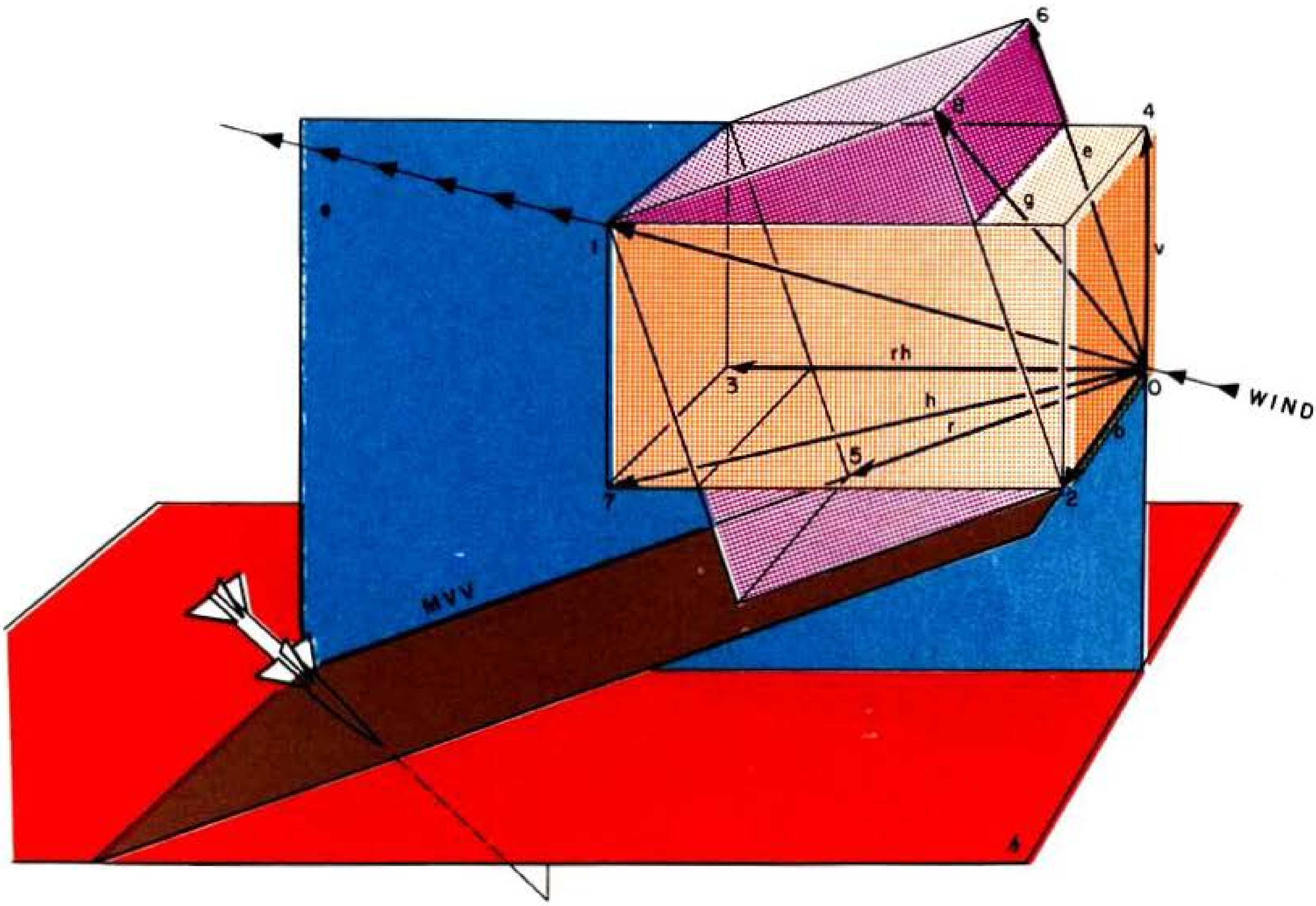

Figure 20—Missile Wind Rates About Missile Velocity Vector in Stable Coordinates.

Table 31

		True wind	Missile wind	Apparent missile wind
Total rate	0–1	***W***	***Wm***	***mWa***
Rate perpendicular to vertical plane through MVV	0–2	***Wb***	***Wbm***	***mWba***
Rate in horizontal in vertical plane through MVV	0–3	***Wrh***	***Wrhm***	***mWrha***
Rate in vertical in vertical plane through MVV	0–4	***Wv***	***Wvm***	***mWva***
Rate along MVV	0–5	***Wr***	***Wrm***	***mWra***
Rate perpendicular to MVV in vertical plane through MVV	0–6	***We***	***Wem***	***mWea***
Rate in horizontal in vertical plane through course line	0–7	***Wh***	***Whm***	***mWha***
Total rate perpendicular to MVV	0–8	***Wg***	***Wgm***	***mWga***

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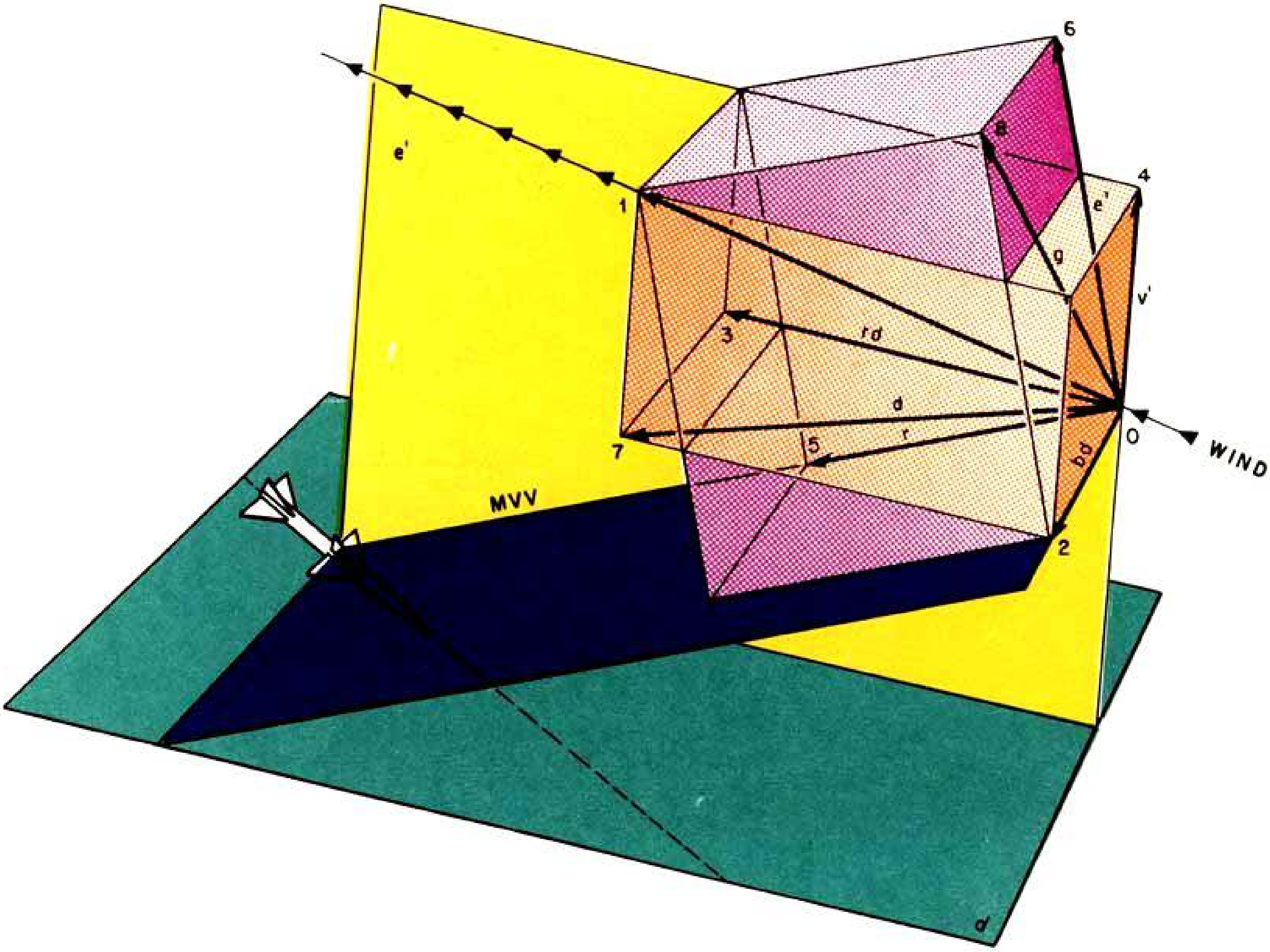

Figure 21—Missile Wind Rates About Missile Velocity Vector in Unstable Coordinates.

Table 32

		True wind	Missile wind	Apparent missile wind
Total rate	0–1	*W*	*Wm*	*mWa*
Rate perpendicular to normal-to-missile-deck plane through MVV	0–2	*Wbd*	*Wbdm*	*mWbda*
Rate in missile deck in normal-to-missile-deck plane through MVV	0–3	*Wrd*	*Wrdm*	*mWrda*
Rate along a line normal-to-missile-deck to missile deck	0–4	*Wv'*	*Wvm'*	*mWva'*
Rate along MVV	0–5	*Wr*	*Wrm*	*mWra*
Rate perpendicular to MVV in normal-to-missile-deck plane through MVV	0–6	*We'*	*Wem'*	*mWea'*
Rate in missile deck in normal-to-missile-deck plane through course line	0–7	*Wd*	*Wdm*	*mWda*

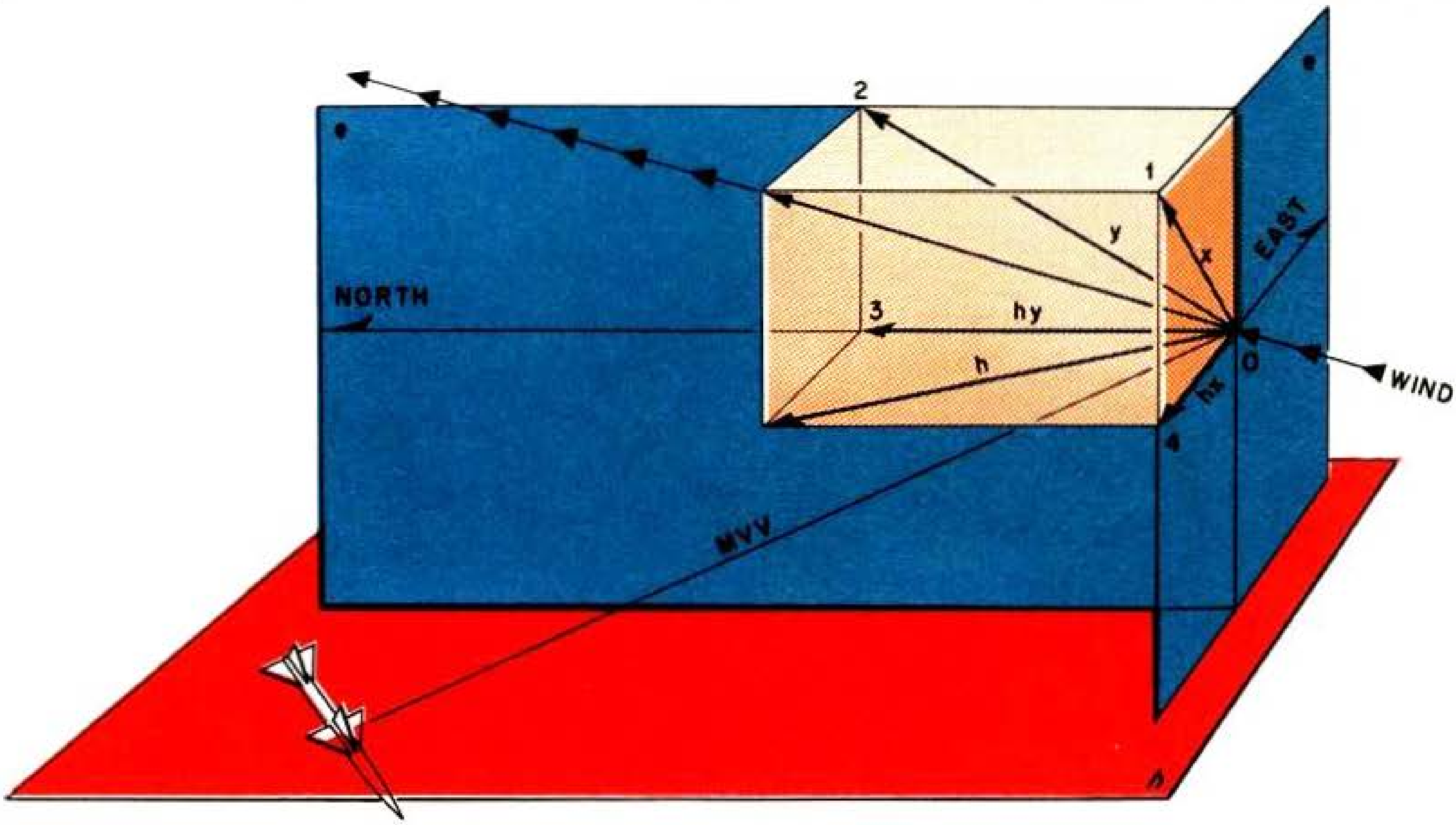

Figure 22—North-South and East-West Projections of Missile Wind Rates in Stable Coordinates.

Table 33

		True wind		Missile wind	Apparent missile wind
Projection of ***W*** in	N–S vertical plane	***Wy***	0–2	***Wym***	***mWya***
	E–W vertical plane	***Wx***	0–1	***Wxm***	***mWxa***
Projection of ***Wh*** in	N–S vertical plane	***Why***	0–3	***Whym***	***mWhya***
	E–W vertical plane	***Whx***	0–4	***Whxm***	***mWhxa***

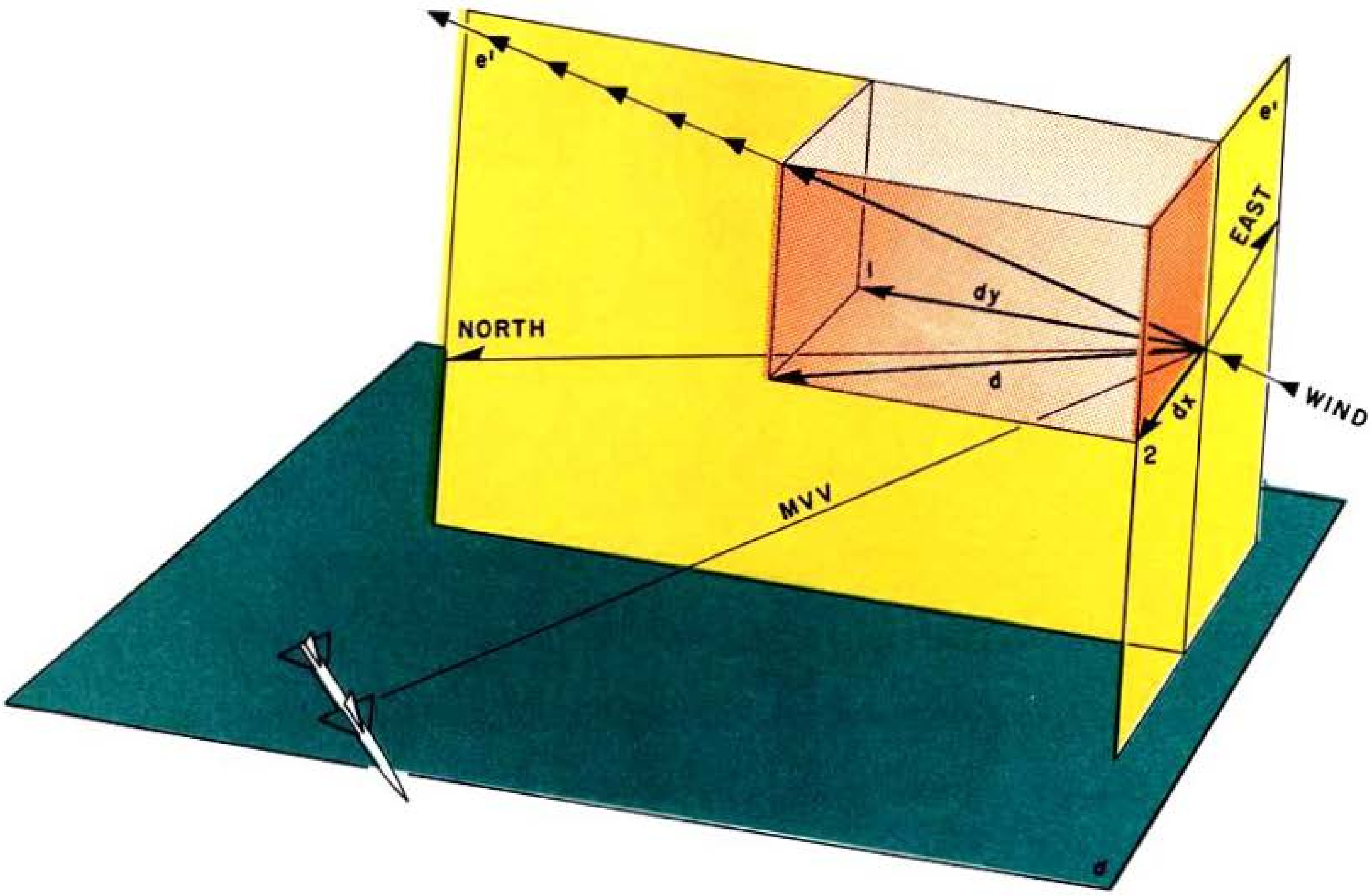

Figure 23—North-South and East-West Projections of Missile Wind Rates in Unstable Coordinates.

Table 34

		True wind	Missile wind	Apparent missile wind
Projection of ***Wd*** in	N–S normal-to-missile-deck plane	0–1 ***Wdy***	***Wdym***	***mWdya***
	E–W normal-to-missile-deck plane	0–2 ***Wdx***	***Wdxm***	***mWdxa***

Chapter 4

OFFSETS AND LAUNCHER ORDERS

Linear and angular offsets are used to establish the position of the line of launch with respect to the line of sight (LOS) or the line of sight to the missile (LSM), in substantially the way described in volume 1, chapter 4. Launcher orders are the computed angular values used to position the launcher along the line of launch, substantially as described in volume 1, chapter 5. Each of these groups of quantities will be discussed in this chapter in terms of the additions and modifications necessary to represent the missile problem.

Linear and Angular Offsets

In addition to future target position and aiming position, the missile problem requires the determination of capture target position—the position the target occupies at missile capture. The location of this position is determined solely from target motion during the time of flight to missile capture, in the frame used by the fire control system.

The aiming position in the missile problem may be determined not only from target motion, but from various limitations that are imposed on launcher position as well. It is, therefore, sometimes necessary to offset the line of sight to the missile (that is, the guidance radar beam) from the line of fire.

Total Offsets. Offsets from the line of fire to the line of sight to the missile are obtained from volume 1, figures 26 and 27 and their associated tables, by adding the missile modifier ***m***, to the basic symbol ***L*** (or ***V***) to form a new basic symbol, ***Lm*** (or ***Vm***), and by replacing the LOS with the LSM wherever it occurs. Components are formed in the usual manner.

In most analyses, fixed offsets are computed for the launching phase of a missile problem. Occasionally, a quantity like ***Lhm*** is generated continuously, after launch, and used in the computation of various guidance quantities. The symbol for a variable offset, however, is not differentiated from that of a fixed offset; the nature of the offset is determined from its application.

The total lead angle, ***L***, measured in a two-axis system, has the same components, sight angle and sight deflection, in either the missile problem or the antiaircraft problem. In the missile problem, however, total lead angle also may be measured in a three-axis system (see chapter 1), and its components then must be differentiated from the two-axis components. Three-axis components are obtained from volume 1, figure 26 and its associated table, by enclosing the required quantities in double parentheses, to indicate that the measurements are made in a three-axis system. This is possible because the three-axis system is essentially one in which the elevation axis supports the traverse axis. For example, to offset the line of sight from the line of fire, using a three-axis system, the following angles may be used:

1. ((***Vsd'***))—sight angle
2. ((***Lsd'***))—sight deflection

To the possible modifiers which may be applied to the various offsets, must be added the numeral ***6***, which indicates that the slant plane passes through the target position at capture.

Individual Offsets. To symbolize individual offsets, the symbol for the lead angle is enclosed in parentheses and preceded by the appropriate quantity modifier or modifiers to indicate that portion of the offset.

Quantity modifiers required for the missile problem and their meanings are:

b	Ballistics
m	Relative motion
p	Launcher parallax
pm	Guidance radar parallax
ps	Tracking radar parallax
r	Launcher rotation
t	Launcher translation
u	Initial velocity
w	Wind

Offsets to Capture Target and Aiming Positions

The offsets to the capture target and aiming positions are expressed as:

1. The angular portions of sight angles and sight deflections measured to these positions, and
2. The linear displacements of these positions from the line of sight or the line of sight to the missile.

To symbolize the portion of a total offset measured to the capture target position, the symbol for the total angle is enclosed in parentheses and preceded by the quantity modifier ***m***. For example, the portion of sight deflection ***Ls*** measured to the capture target position is symbolized as ***m(Ls)***. This symbolization has been selected because the location of the capture target position is determined solely from target motion during the time of flight to missile capture.

Symbols for offsets to the aiming position are the symbols for the total lead angles themselves.

The class of quantities expressing linear displacements to the capture target and aiming positions is represented by the basic symbol ***M*** (or ***mM***) followed by the numeral modifier ***6*** for capture target position, forming symbol ***M6*** (or ***mM6***), and by numeral modifier ***4*** for aiming position, forming symbol ***M4*** (or ***mM4***). Useful components of these displacements are defined, illustrated, and symbolized herein in chapter 2 and in volume 1, chapter 2.

Coordinates of Future, Capture Target, Missile Capture, and Aiming Positions

The measurements to determine the locations of the future, capture target, missile capture, and aiming positions are made in the same reference frames and by the same types of coordinate systems as are used to determine present target and missile positions. The classes of quantities expressing these positions are also the same as those used to express present target and missile positions. To denote measurements of these quantities to the various positions, the following modifiers are used: numeral ***2*** signifies future target position; numberal ***6***, capture target position; numeral ***6*** and letter ***m***, missile capture position; and numeral ***4***, aiming position. For example, for present target position coordinates ***Bd′***, ***Ed′***, and ***R***, the corresponding coordinates for capture target position are ***Bd6′***, ***Ed6′***, and ***R6***; for present missile position coordinates ***Bdm′***, ***Edm′***, and ***Rm***, the corresponding coordinates for missile capture position are ***Bdm6′***, ***Edm6′***, and ***Rm6***.

To express aiming position, symbols for range and range components of present target position are terminated by numeral modifier ***4***, while symbols for bearing and elevation quantities are terminated by modifier ***g***, since these are the angular measurements to the line of fire. For example, for present target position coordinates ***B***, ***E***, and ***R***, the corresponding coordinates for aiming position are ***Bg***, ***Eg***, and ***R4***.

In figure 24, bearing and elevation angles used to express the location of the capture target posi-

Table 35

			To vertical plane through line to capture target position	To normal-to-deck plane through line to capture target position
Bearing	In horizontal plane	From N–S vertical plane	***By6*** 1–4	***By6′*** 1–5
		From vertical plane through OSCL	***B6*** 3–4	***B6′*** 3–5
	In deck plane	From N–S vertical plane	***Bdy6*** 6–8	***Bdy6′*** 6–10
		From vertical plane through OSCL	***Bd6*** 7–8	***Bd6′*** 7–10

Table 36

		In vertical plane through line to capture target position	In normal-to-deck plane through line to capture target position
Elevation	From horizontal plane	4–11 ***E6***	5–11 ***E6′***
	From deck plane	8–11 ***Ed6***	10–11 ***Ed6′***

tion are shown with numerals indicating the arc measuring each angle. In figure 25, range and range components expressing capture target position are shown with numerals indicating the distances. In composite tables 35, 36, and 37, each bearing, elevation, and range component of capture target position is defined and symbolized.

For example, in figure 24, bearing of the capture target position from the N–S vertical plane to the vertical plane through the line to this position, measured in the horizontal plane, is illustrated as the angle 1–4. In composite table 35, this angle is defined and symbolized ***By6.***

In figure 26, bearing and elevation angles used to express the location of the missile capture

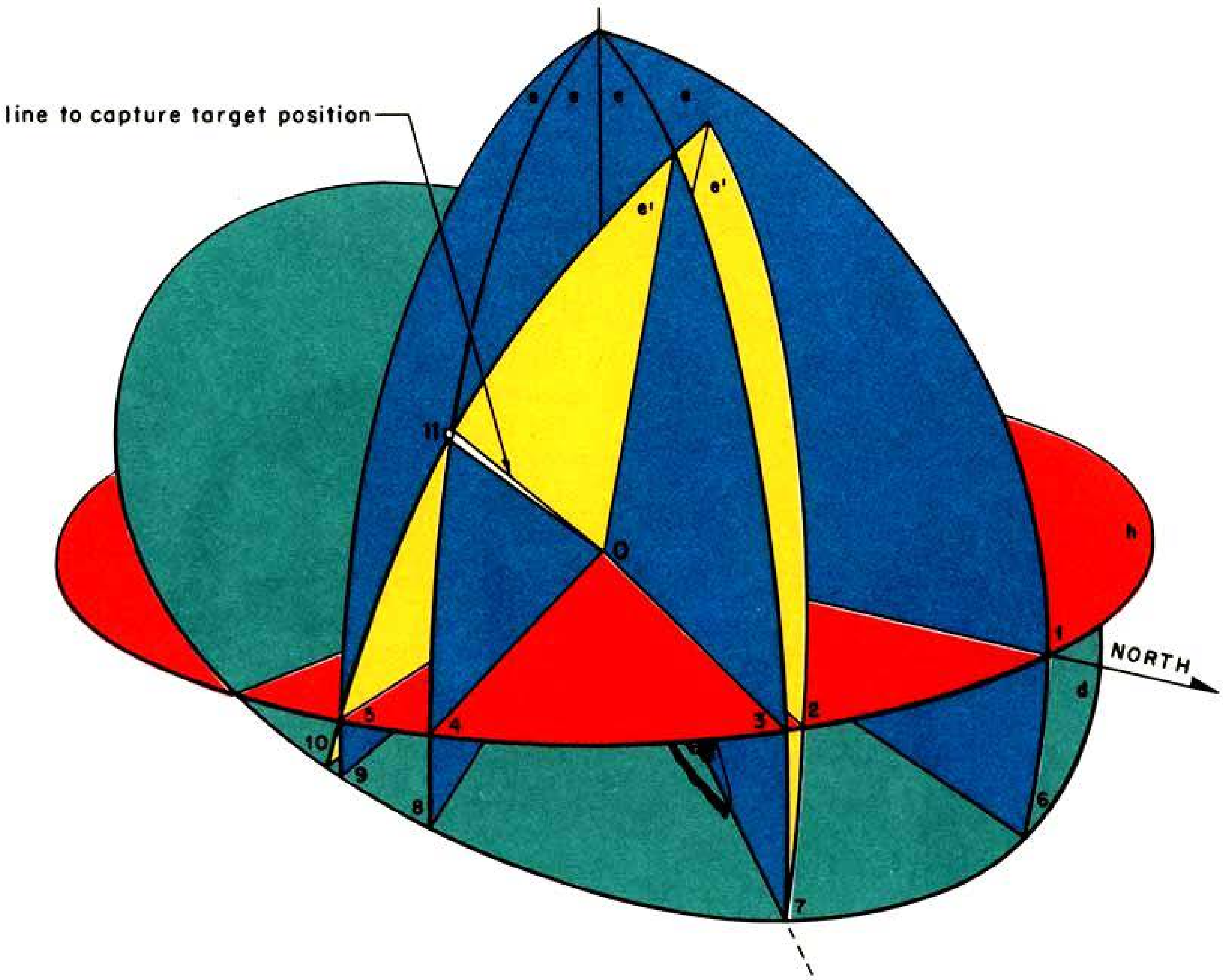

Figure 24—Angular Coordinates of Capture Target Position.

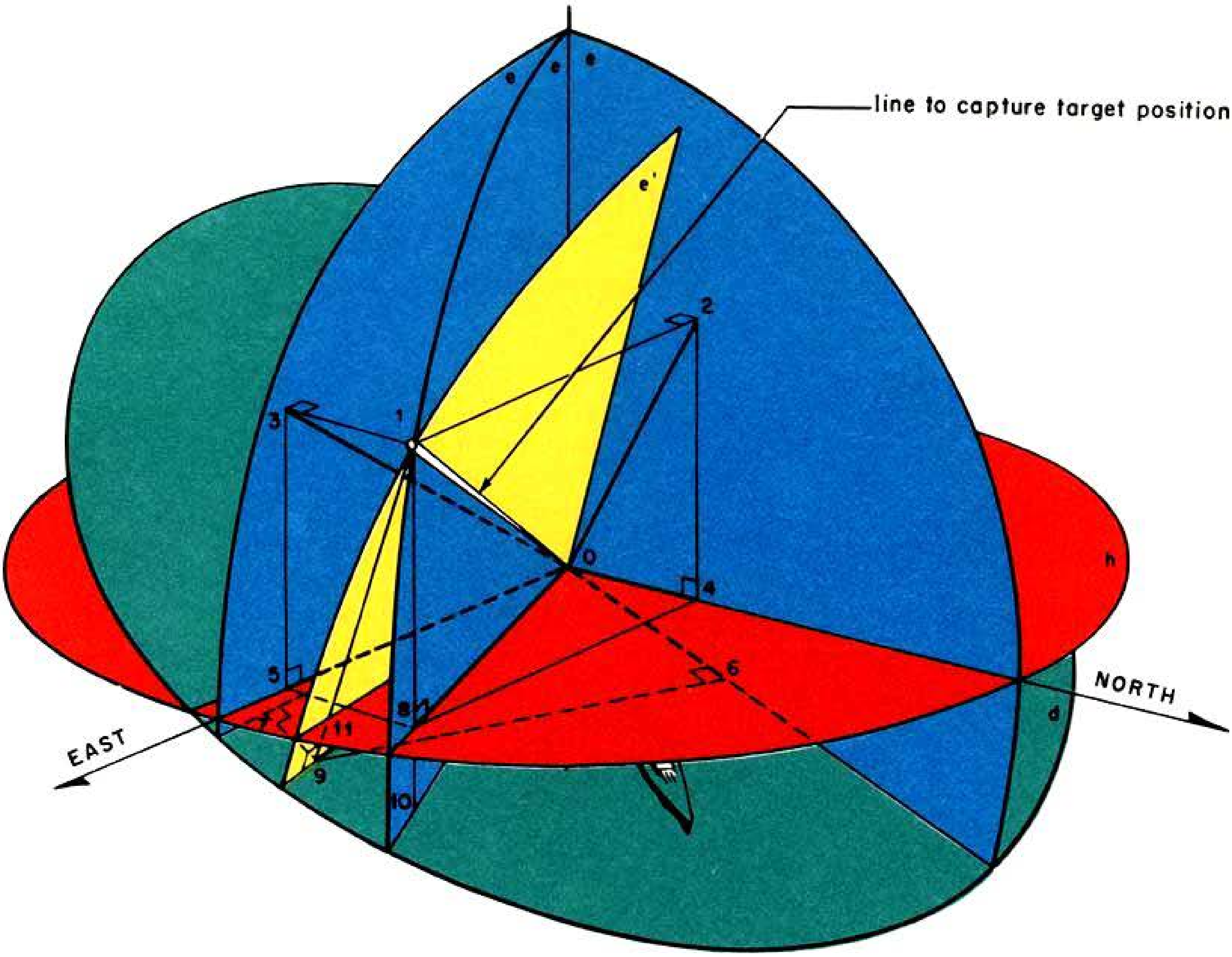

Figure 25—Ranges and Heights of Capture Target Position.

position are shown with numerals indicating the arc measuring each angle. In figure 27, range and range components expressing missile capture position are shown with numerals indicating the distances. In composite tables 38, 39, and 40, each bearing, elevation and range component of missile capture position is defined and symbolized.

For example, in figure 26 bearing of the missile capture position from the N–S vertical plane to the vertical plane through the line to this position, measured in the horizontal plane, is illustrated as the angle 1–4. In composite table 38, this angle is defined and symbolized ***Bmy6***.

Coordinates of future target position are illustrated, defined, and symbolized in volume 1, figures 28 and 29, and composite tables 28A, 28B, and 29.

Coordinates of the aiming position, the orders positioning the launcher along the line of fire, are illustrated, defined, and symbolized in volume 1, chapter 5, and described in the following paragraph.

Table 37

					N-S Components	E-W Components
Range	Along line to capture target position			0-1 *R6*	0-2 *Ry6*	0-3 *Rx6*
	Along intersection of	Vertical plane through line to capture target position	and horizontal	0-8 *Rh6*	0-4 *Rhy6*	0-5 *Rhx6*
		Normal-to-deck plane through line to capture target position	and deck	0-9 *Rd6*	0-6 *Rdy6*	0-7 *Rdx6*

		In vertical plane through line of capture target position	In normal-to-deck plane through line to capture target position
Height	Above horizontal	8-1 *Rv6*	11-1 *Rv6′*
	Above deck	10-1 *Rvd6*	9-1 *Rvd6′*

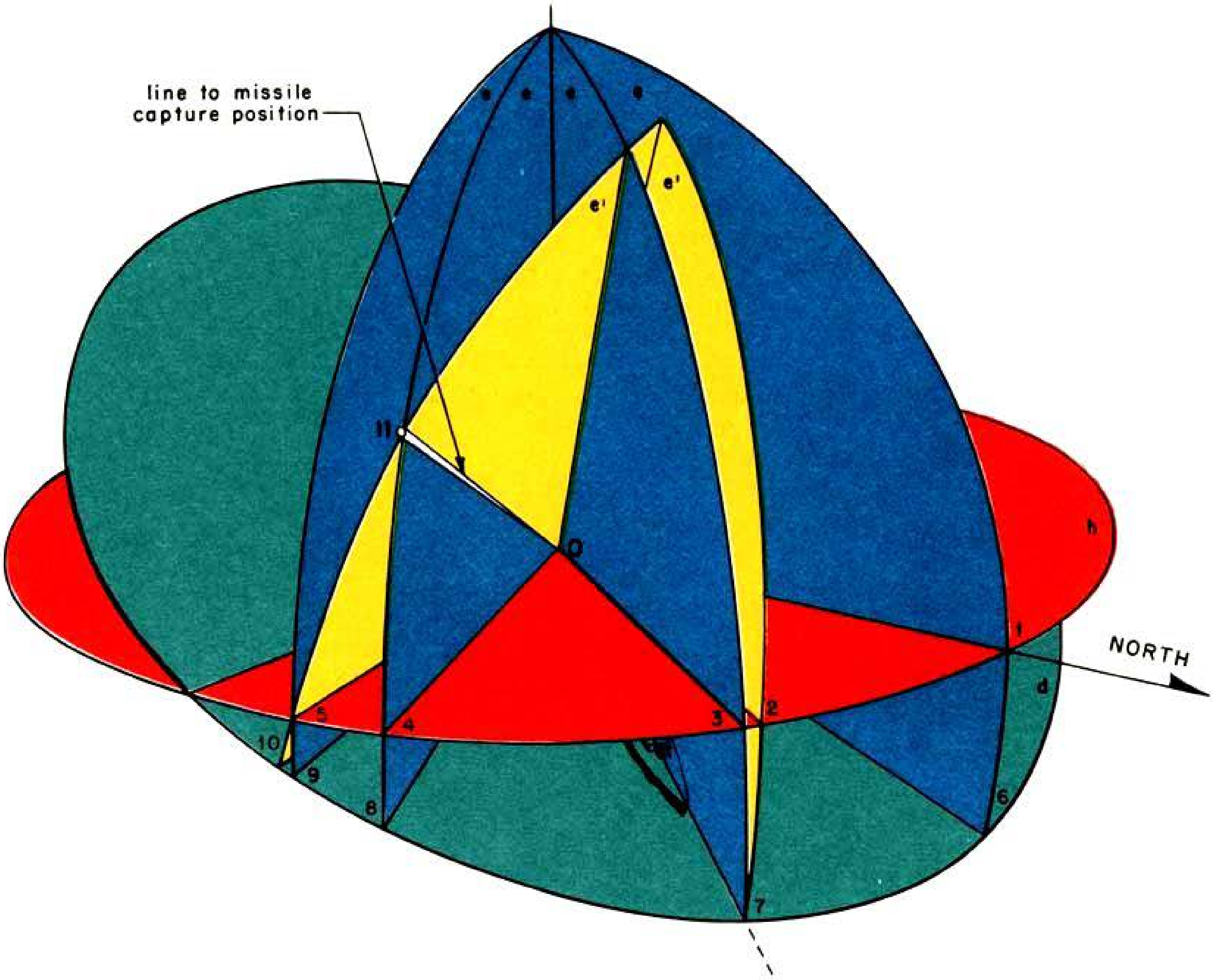

Figure 26—Angular Coordinates of Missile Capture Position.

Table 38

			To vertical plane through line to missile capture position	To normal-to-deck plane through line to missile capture position
Bearing	In horizontal plane	From N–S vertical plane	*Bmy6* 1–4	*Bmy6′* 1–5
		From vertical plane through OSCL	*Bm6* 3–4	*Bm6′* 3–5
	In deck plane	From N–S vertical plane	*Bdmy6* 6–8	*Bdmy6′* 6–10
		From vertical plane through OSCL	*Bdm6* 7–8	*Bdm6′* 7–10

Table 39

		In vertical plane through line to missile capture position	In normal-to-deck plane through line to missile capture position
Elevation	From horizontal plane	*Em6* 4–11	*Em6′* 5–11
	From deck plane	*Edm6* 8–11	*Edm6′* 10–11

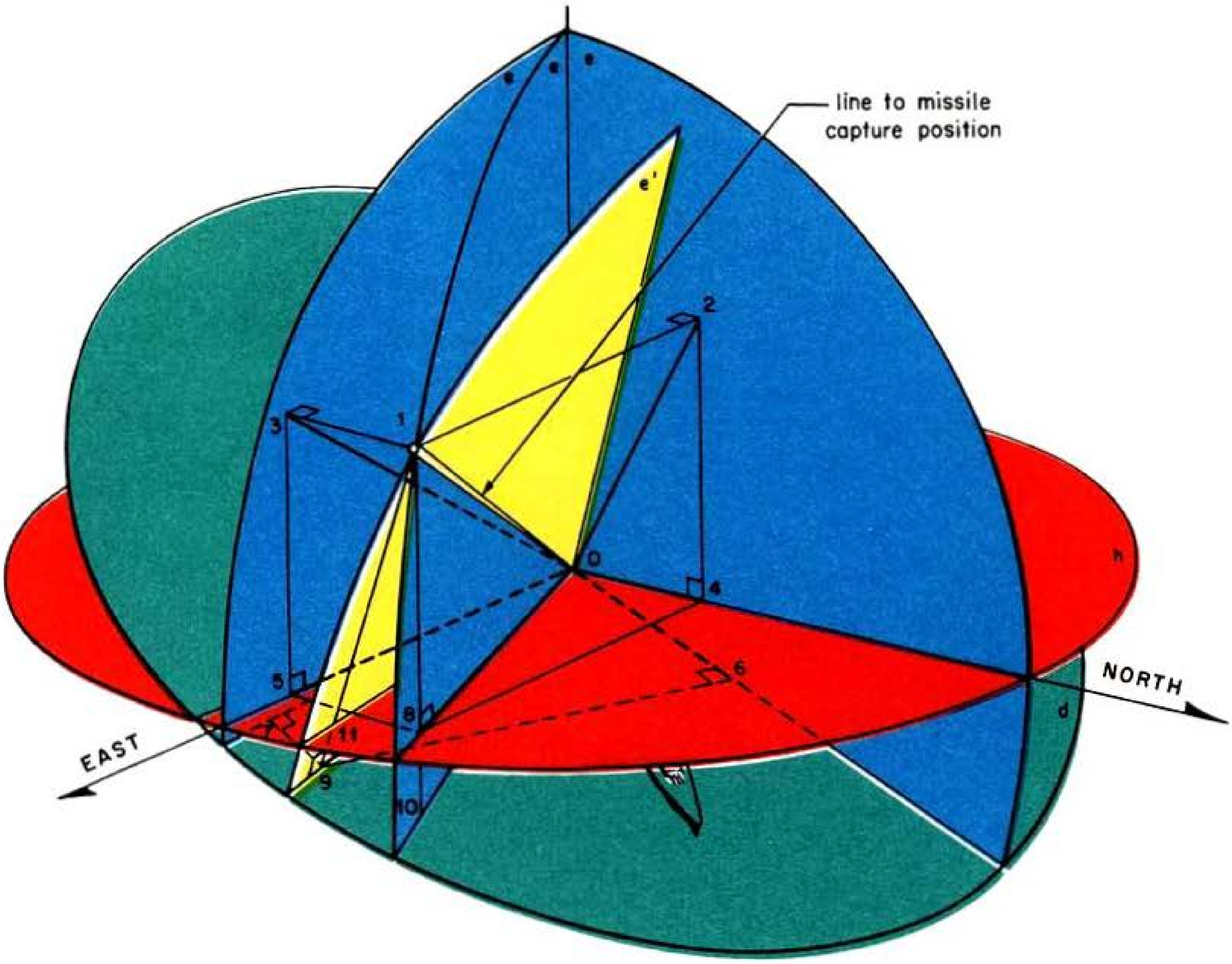

Figure 27—Ranges and Heights of Missile Capture Position.

Table 40

					N–S Components	E–W Components
Range	Along line to missile capture position			0–1 ***Rm6***	0–2 ***Rmy6***	0–3 ***Rmx6***
	Along intersection of	Vertical plane through line to missile capture position	And horizontal	0–8 ***Rhm6***	0–4 ***Rhmy6***	0–5 ***Rhmx6***
		Normal-to-deck plane through line to missile capture position	And deck	0–9 ***Rdm6***	0–6 ***Rdmy6***	0–7 ***Rdmx6***

		In vertical plane through line to missile capture position	In normal-to-deck plane through line to missile capture position
Height	Above horizontal	8–1 ***Rmv6***	11–1 ***Rmv6′***
	Above deck	10–1 ***Rdmv6***	9–1 ***Rdmv6′***

Launcher Orders

Missile launcher orders and related quantities are identical with the gun orders and related quantities described in volume 1, chapter 5. In volume 1, chapter 5, however, no distinction is made between gun orders and actual gun positions. In the missile problem, this distinction is sometimes necessary, and appropriate symbolization is therefore required.

Ordinarily, a launcher order such as ***Bdg′***, for example, represents both the launcher train order and the actual launcher train position, since these are often identical. When they differ, as after loading, the symbol ***Bdg′*** is retained for the actual launcher train position, and a new symbol, ***Bdgl′***, is used for the launcher train order. This is formed by applying the numeral modifier ***1***, signifying the instant of launch, to the old symbol ***Bdg′***.

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Chapter 5

GUIDANCE

The guidance phase of the missile problem may be divided further into two related problems. The first, keeping the missile in the guidance radar beam, is concerned primarily with the transmission of intelligence to the missile. The second, moving the guidance beam to result in interception, is largely tactical, but obviously depends on missile parameters as well.

Phasing

Keeping the missile in the guidance radar beam is accomplished by transmitting up-down and right-left signals to the missile control system. In order that the missile sense these signals properly, the missile vertical reference must correspond with the radar vertical reference. Bringing these references into coincidence, termed "phasing", is one of the problems of intelligence transmission to the missile.

Geometrically, phasing is accomplished by projecting both the radar vertical and the missile vertical onto the radar boresight plane (a plane perpendicular to the line of sight to the missile) and rotating the radar projection about the LSM into the missile projection, as shown in figure 28. The resultant angle of rotation is the guidance phasing error, sym-

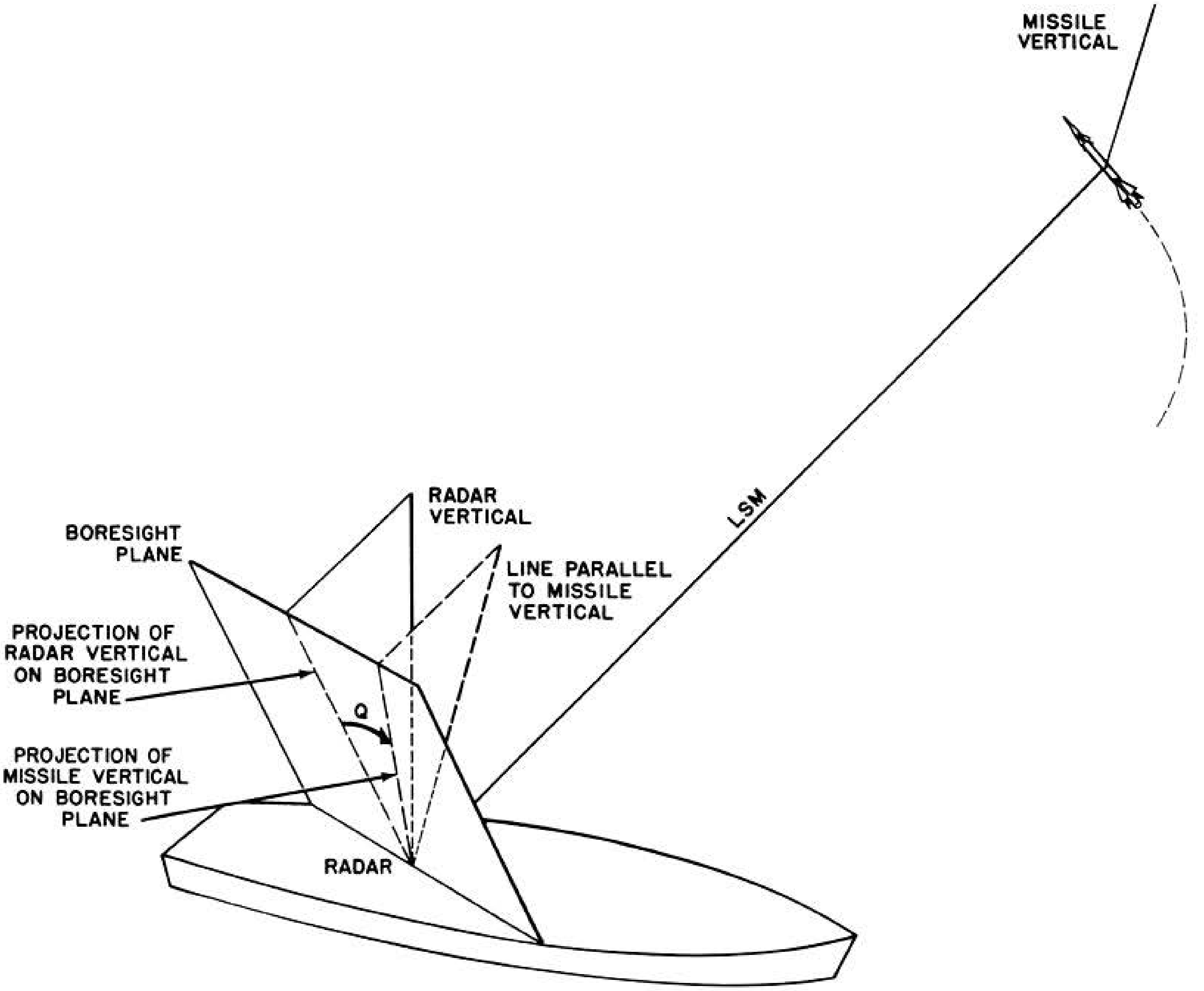

Figure 28—The Guidance Phase.

bolized by the letter ***Q***. In actual practice, the position of the projection of the missile vertical on the boresight plane is computed, and ***Q*** is therefore not known exactly. The computed value of ***Q*** is called the guidance phasing order, and when it is necessary to distinguish it from the guidance phasing error, modifier ***1*** is added to form symbol ***Q1***.

The angle ***Q*** is in reality a relative phase angle; that is, it represents the difference in phase between the normal guidance beam modulation and this modulation corrected for missile vertical misalignment. It is also necessary to specify the instantaneous phase of the guidance beam modulation, symbolized ***Qn***, the modifier ***n*** referring to beam mutation. Instantaneous phase ***Qn*** is sometimes biased, and the bias is symbolized ***q(Qn)***.

Closely related to ***Q*** is ***Zsm***, guidance radar cross traverse (see chapter 1). Another quantity of importance is the angle between the vertical plane through the line of sight to the missile and the plane through the instantaneous position of the nutating radar beam and the line of sight to the missile. This angle, called nutation cross traverse, and symbolized ***Zmn***, is related to instantaneous phase angle ***Qn***.

Although the angle ***Q*** is defined geometrically, for convenience, it is a phase angle, as are the rest of the class of quantities symbolized by the letter ***Q***. The class ***Q*** is thus distinguished from the class of quantities symbolized by the letter ***Z***, which are all geometrical angles.

Phasing order ***Q*** is computed in parts, each part accounting for a different effect causing missile vertical misalignment. Parts of ***Q*** are symbolized by enclosing ***Q*** in parentheses and prefixing appropriate modifiers. Modifiers that are now used are:

m______ Misalignment due to missile angular displacement from the line of launch.

mg_____ Misalignment due to angular velocity of guidance radar beam.

q_______ Bias (or spot).

Thus, a simplified equation for ***Q*** may be written as:

$$Q=m(Q)+mg(Q)+q(Q)$$

Crossing Angle (Figure 29). The angle between the line of sight from the director to the missile and the missile velocity vector, called "beam crossing angle" and symbolized ***mG***, is important in both the launching and guidance phases of the missile problem. During the launching phase, crossing angle at capture, ***mG6*** (***6*** indicating time of capture), is predicted and used in turn to compute other launching quantities. After capture, computed crossing angle, ***c*** (***mG***), is used in computing the radar phasing order, ***Q***. The angle between the line from the launcher to future position of target and the missile velocity vector, called "***R2*** crossing angle" and symbolized ***mGg*** is important in missiles that home on the target (see figure 30).

Crossing angles may be resolved into elevation and slant (or horizontal or deck) components in exactly the same way as total lead angle ***L***, since, like ***L***, it is an offset angle between two lines in space. In order to obtain components of ***mG*** from volume 1, figures 26 and 27 and their associated tables, it is only necessary to substitute LSM for LOS and MVV for LOF wherever they occur, and ***mGe*** for ***Vs*** and ***mG*** or ***mGg*** for ***L***. For example, the component of ***mG*** normal to zero-cross-traverse slant plane is symbolized ***mGe***.

Missile Offsets

Linear and angular offsets of the missile from the target are important quantities in computing the program according to which the guidance beam is moved to result in interception. The class of linear offsets represented by the symbol ***mM***, relative guidance displacement, is discussed in chapter 2. The angle between the line of sight to the missile and the line of sight, called "missile offset angle" is symbolized by the letter ***F***, and its components, complete the specification of missile offsets. Missile offset angle is resolved into elevation and slant (or horizontal or deck) components in exactly the same way as the total lead angle, ***L***, since like ***L***, it is an offset angle between two lines in space. In order to obtain components of ***F*** from volume 1, figures 26 and 27 and their associated tables, it is only necessary to substitute LSM for LOS and LOS for LOF wherever they occur, and ***Fe*** for ***Vs*** and ***F*** for ***L***. For

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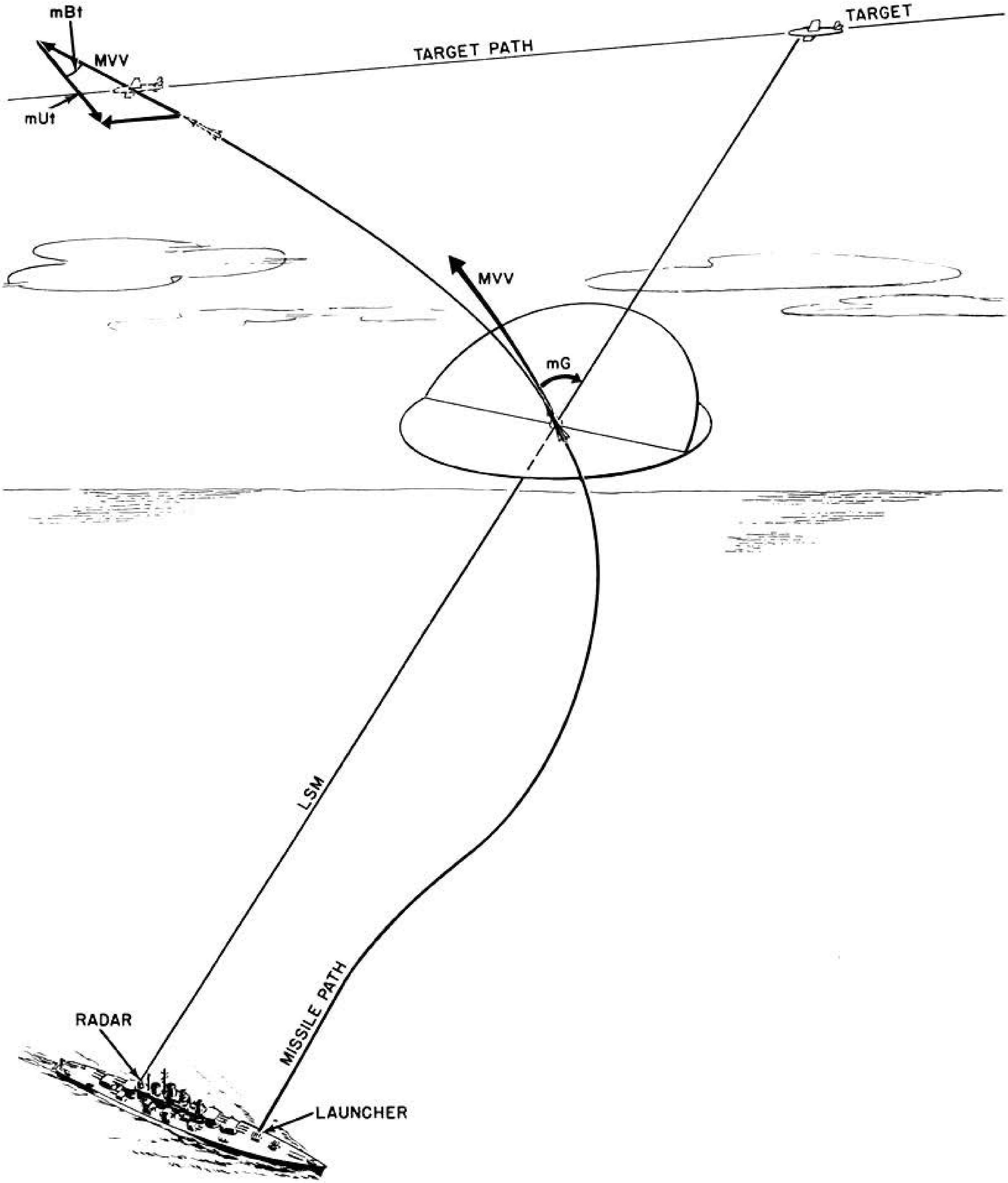

Figure 29—Crossing Angle, Beam Capture Missile.

example, the angle between the normal-to-deck plane through the line of sight and the normal plane through the line of sight to the missile, measured in the deck plane from the normal plane through the line of sight to the missile, is symbolized ***'Fd'***.

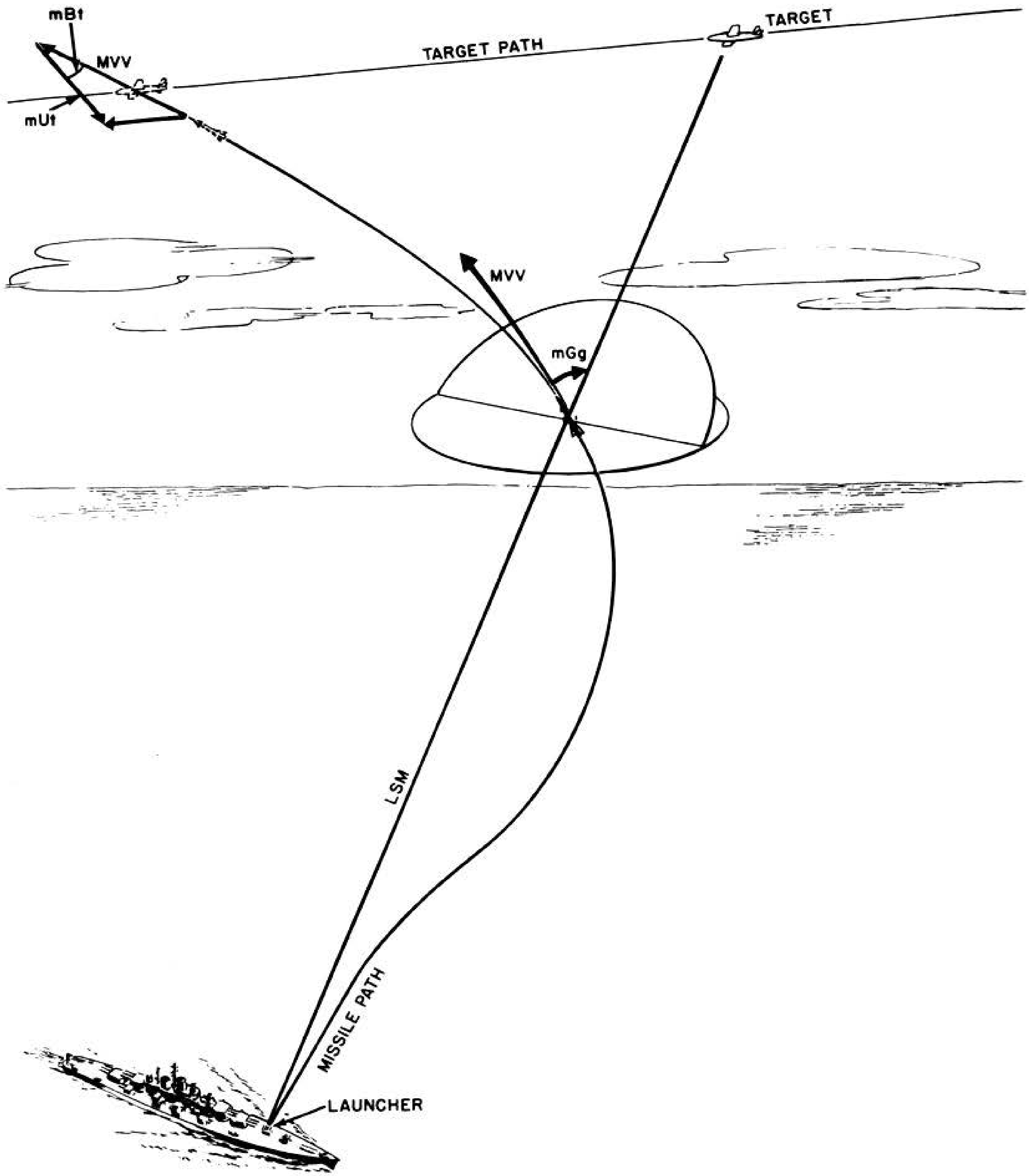

Figure 30—Crossing Angle, Homing Missile.

DICTIONARY OF SYMBOLS

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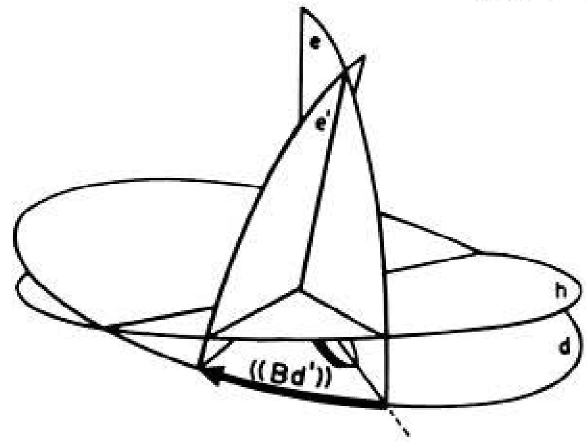
((Bd'))

Director Train

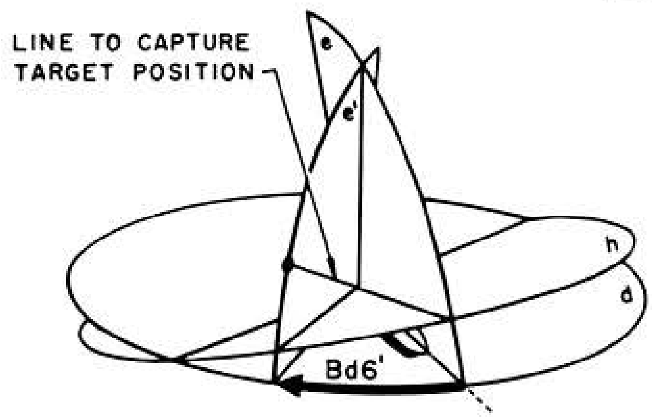
Angle between the vertical plane through own ship centerline and a normal-to-deck elevation plane measured in the deck plane in a three axis system. Positive angles measured clockwise from own ship centerline.



Bd6'

Director Train at Capture

Angle between the vertical plane through own ship centerline and the normal-to-deck plane through the line to the capture target position measured in the deck plane. Positive angles measured clockwise from own ship centerline.



Bdg1'

Launcher Train Order

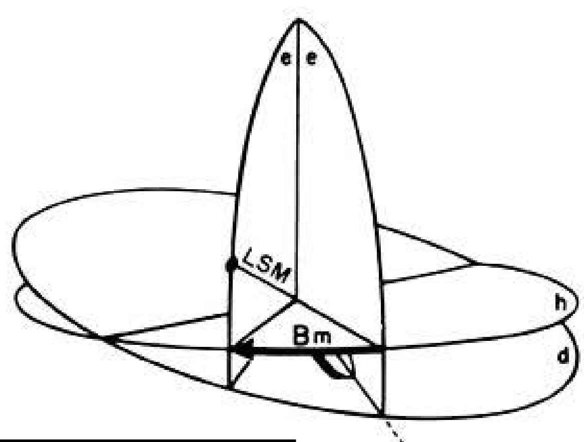
Angle between the vertical plane through own ship centerline and the normal-to-deck plane through the line of launch measured in the deck plane. Positive angles measured clockwise from own ship centerline.

Note: 1. This symbol is used only when the launcher train order differs from actual launcher train.

Bm

Relative Missile Bearing

Angle between the vertical plane through own ship centerline and the vertical plane through the line of sight to the missile measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.



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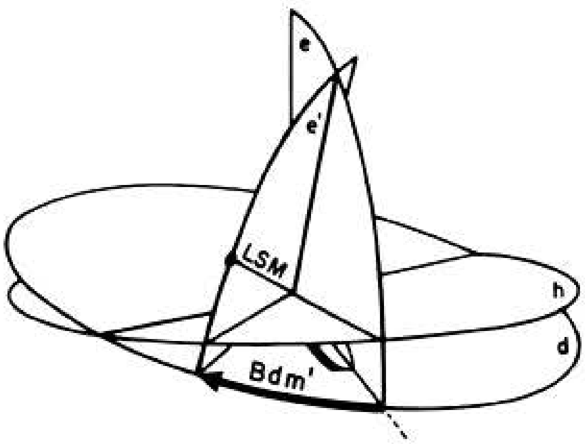
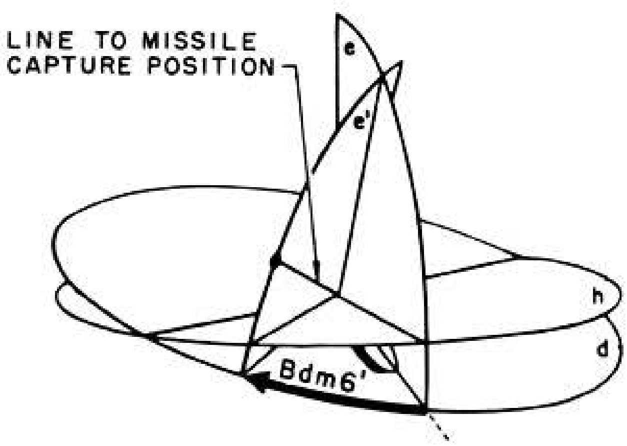
Bdm′



Guidance Train (Unstabilized)

Angle between the vertical plane through own ship centerline and the normal-to-deck plane to the line of sight to the missile measured in the deck plane. Positive angles measured clockwise from own ship centerline.

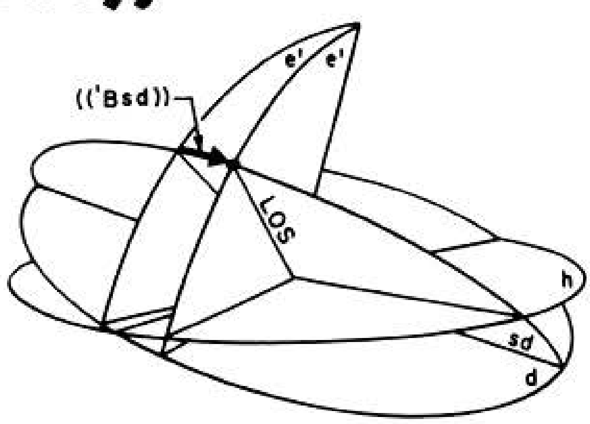
Bdm6′



Guidance Train at Capture

Angle between the vertical plane through own ship centerline and the normal-to-deck plane through the line to the missile capture position measured in the deck plane. Positive angles measured clockwise from own ship centerline.

(('Bsd))



Director Traverse

Angle between the line of sight and a normal elevation plane measured from the normal-to-deck elevation plane in the slant plane through the line of sight and through the director elevation axis in the deck plane of a three axis system.

By1

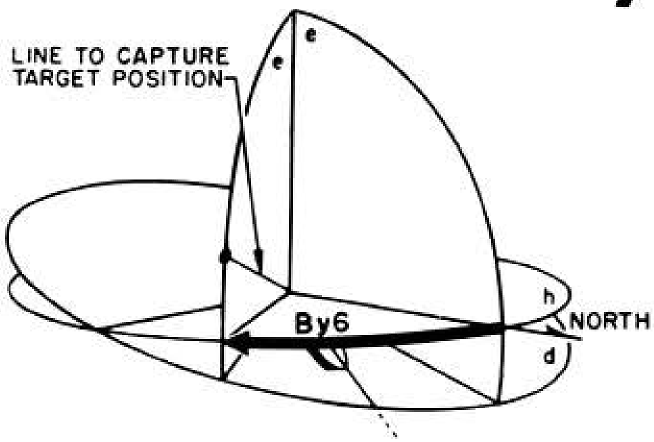
True Target Bearing at Launch

See Note 2 under ***By*** in Volume 1.

By6

True Target Bearing at Capture

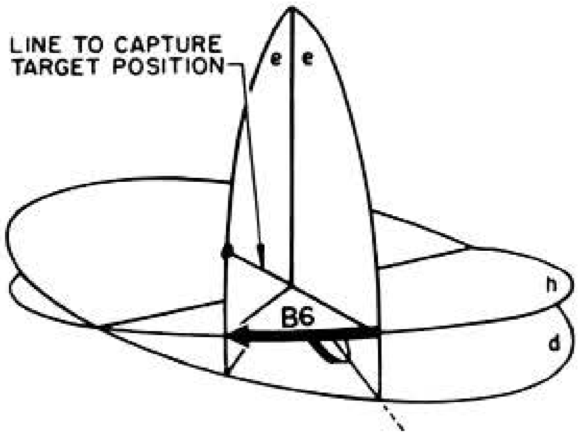
Angle between the North-South vertical plane and the vertical plane through the line to the capture target position measured in the horizontal plane. Positive angles measured clockwise from the North.



B6

Relative Target Bearing at Capture

Angle between the vertical plane through own ship centerline and the vertical plane through the line to the capture target position measured in the horizontal plane. Positive angles measured clockwise from own ship centerline.



mBt

Angle between missile velocity vector and vector difference between missile and target velocities immediately before interception.

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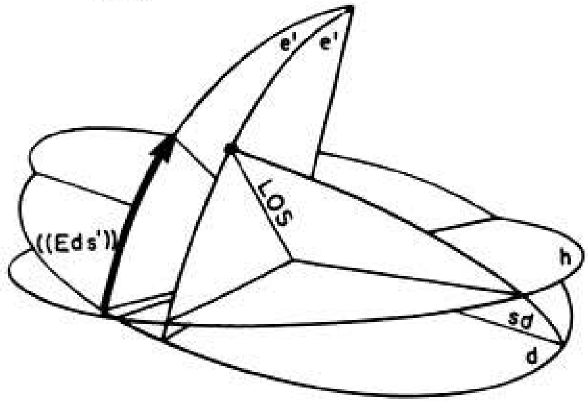
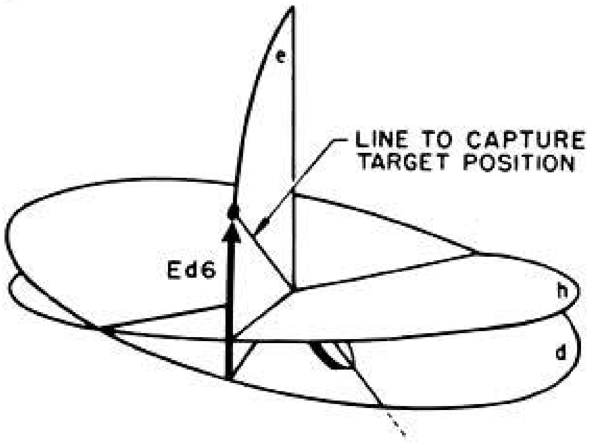
((Eds′))



Director Elevation

Angle between the deck plane and a slant traverse plane measured in a normal-to-deck elevation plane. Positive angles measured upward from the deck plane.

Ed6



Director Elevation at Capture

Angle between the deck plane and the line to the capture target position measured in the vertical plane through the line to the capture target position. Positive angles measured upward from the deck plane.

Edg1′

Launcher Elevation Order

Angle between the deck plane and the line of launch measured in the normal-to-deck plane through the line of launch. Positive angles measured upward from the deck plane.

Note: 1. This symbol is used only when the launcher elevation order differs from actual launcher elevation.

Ei6

Level Angle at Capture

See Note 2 under ***Ei*** in Volume 1.

Eim

Guidance Level

Angle between the horizontal plane and the deck plane measured in the vertical plane through the line of sight to the missile. Positive angles measured downward from the horizontal plane on the missile side of own ship.

Note: 1. To express the same quantity at the time of capture modifier ***6*** is added and symbol is ***Eim6***.

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Eim6

Guidance Level at Capture

See Note 1 under *Eim.*

Eio6

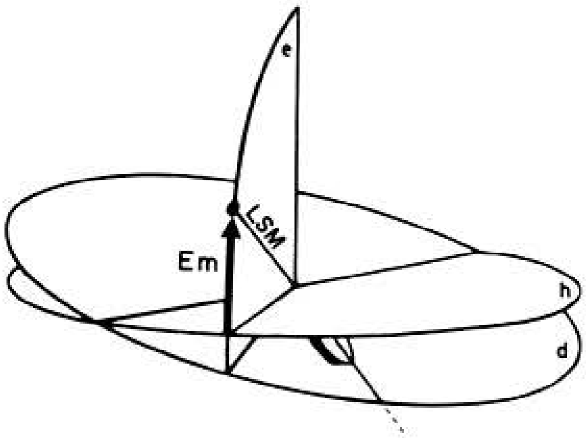
Pitch at Capture

See Note 2 under *Eio* in Volume 1.

Em

Missile Elevation

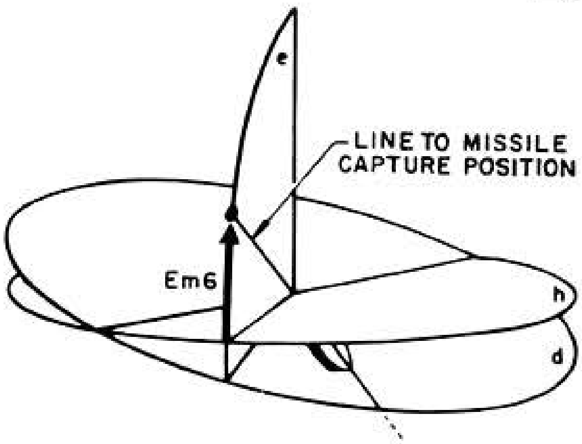
Angle between the horizontal plane and the line of sight to the missile measured in the vertical plane through the line of sight to the missile. Positive angles measured upward from the horizontal plane.



Em6

Missile Elevation at Capture

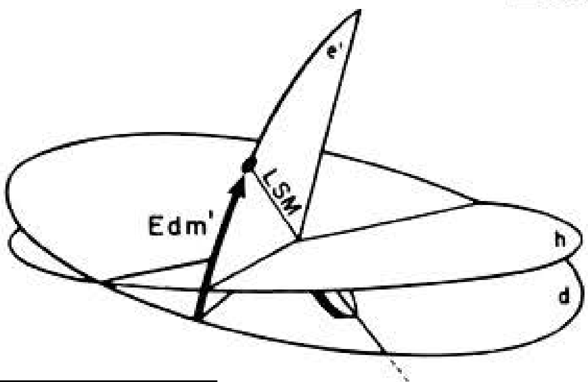
Angle between the horizontal plane and the line to the missile capture position measured in the vertical plane through the line to the missile capture position. Positive angles measured from the horizontal plane.



Edm′

Guidance Elevation

Angle between the deck plane and the line of sight to the missile measured in the normal-to-deck plane through the line of sight to the missile. Positive angles measured upward from the deck plane.



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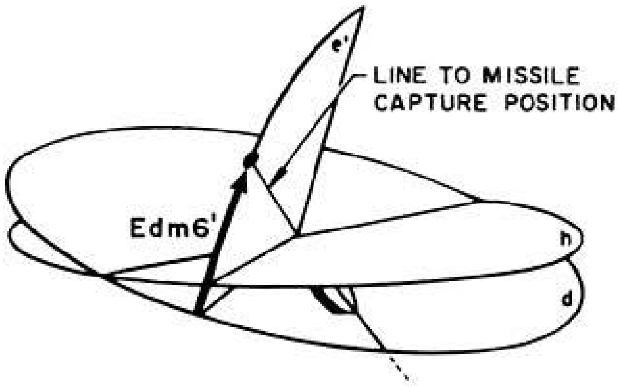
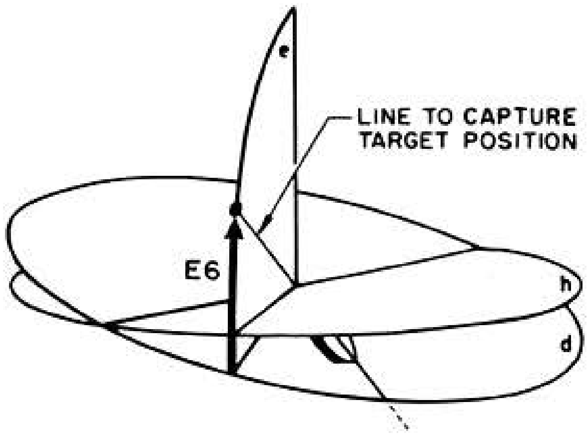
Edm6'



Guidance Elevation at Capture

Angle between the deck plane and the line to the missile capture position measured in the normal-to-deck plane through the line to the missile capture position. Positive angles measured upward from the deck plane.

E6



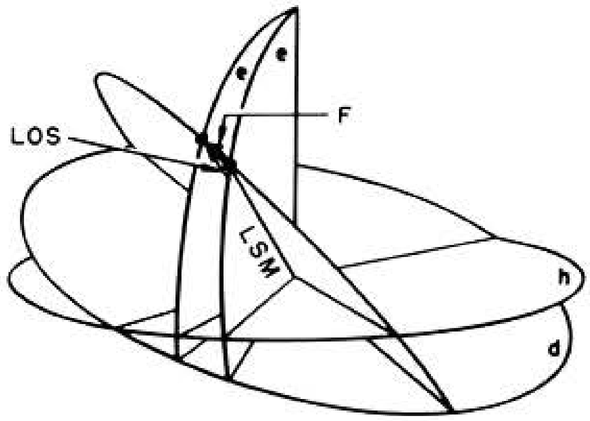
Target Elevation at Capture

Angle between the horizontal plane and the line to the capture target position measured in the vertical plane through the line to the capture target position. Positive angles measured upward from the horizontal plane.

F

Missile Offset Angle

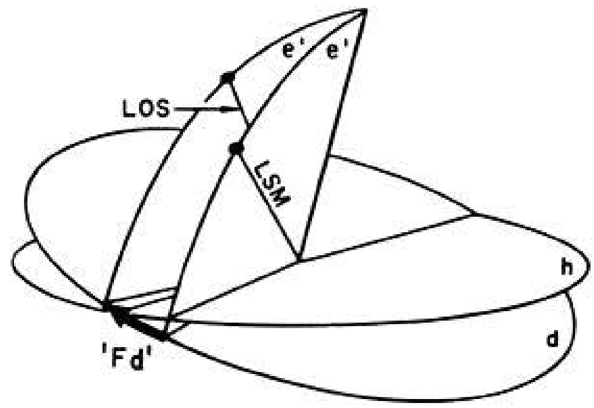
Angle between the line of sight and the line of sight to the missile.



'Fd'

Deck Component of Missile Offset Angle

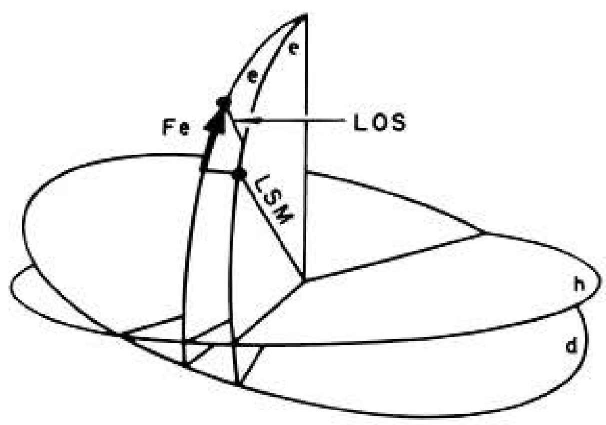
Angle between the normal-to-deck plane through the line of sight and the normal plane through the line of sight to the missile. (***'FD'*** $=$ ***Bd'*** $-$ ***Bdm'***)



Fe

Elevation Component of Missile Offset Angle

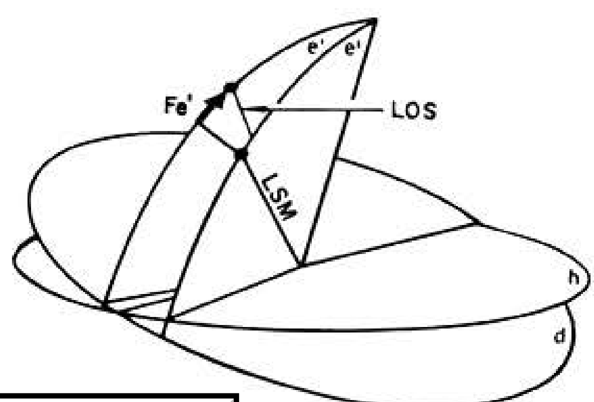
The difference in elevation between the line of sight and the line of sight to the missile, measured in a vertical plane. (***Fe*** $=$ ***Ed*** $-$ ***Edm***)



Fe'

Elevation Component of Missile Offset Angle

The difference in elevation between the line of sight and the line of sight to the missile, measured in a normal plane. (***Fe'*** $=$ ***Ed'*** $-$ ***Edm'***)



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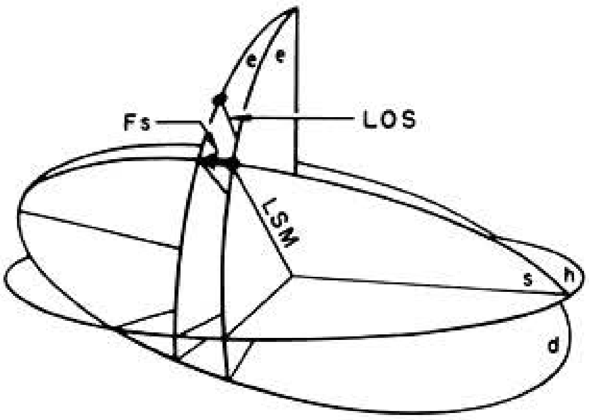
Fs



Slant Component of Missile Offset Angle

Angle between the line of sight and the vertical plane through the line of sight to the missile measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane.

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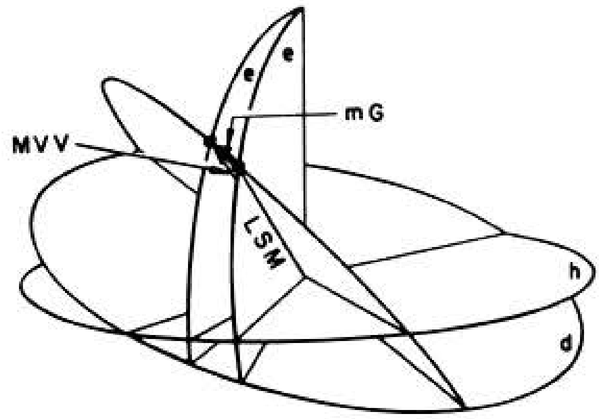
mG

Beam Crossing Angle

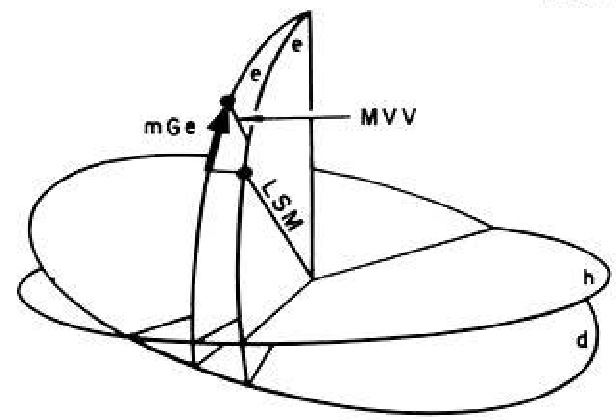
Angle between the line of sight from the director to the missile and the missile velocity vector.



mGe

Elevation Component of Beam Crossing Angle

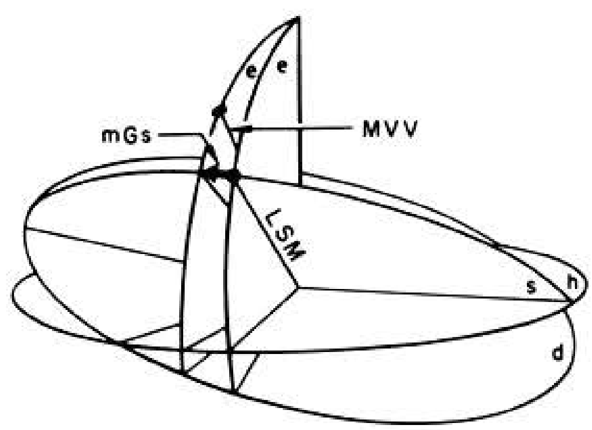
Component of *mG* normal to zero-cross-traverse slant plane.



mGs

Slant Component of Beam Crossing Angle

Component of *mG* in zero-cross-traverse slant plane.



mGg

R2 Crossing Angle

Angle between line from the launcher to future position of target and the missile velocity vector.

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mGge

Elevation Component of *R2* Crossing Angle

Component of ***mGg*** normal to zero-cross-traverse slant plane referenced to line from launcher to future position of target.

mGgs

Slant component of ***mGg*** in zero-cross-traverse slant plane referenced to line from launcher to future position of target.

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K

Arbitrary Constant

Symbol used wherever an arbitrary numerical constant is required. It must be defined for every application.

Note: 1. When more than one constant is required in a particular application numerical modifiers are added to form constants ***K1, K2, K3,*** etc.

Lhl

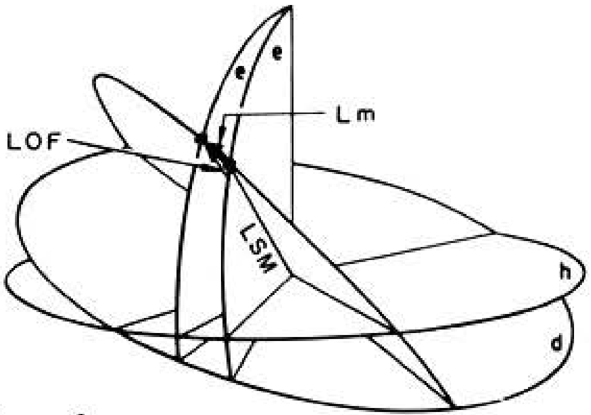
Horizontal Deflection at Launch

See Note 2 under ***Lh*** in Volume 1.

Lm

Total Guidance Lead Angle

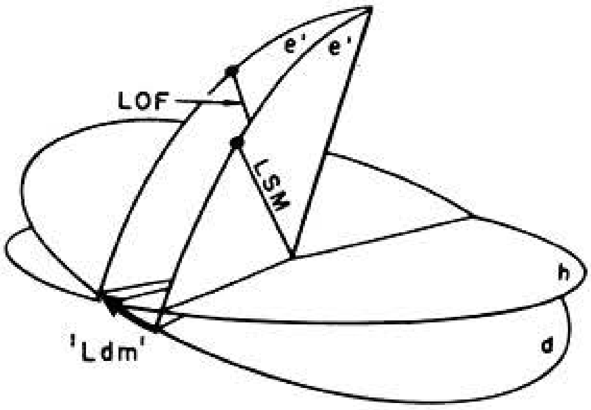
Angle between the line of sight to the missile and the line of launch.



'Ldm'

Guidance Deck Deflection

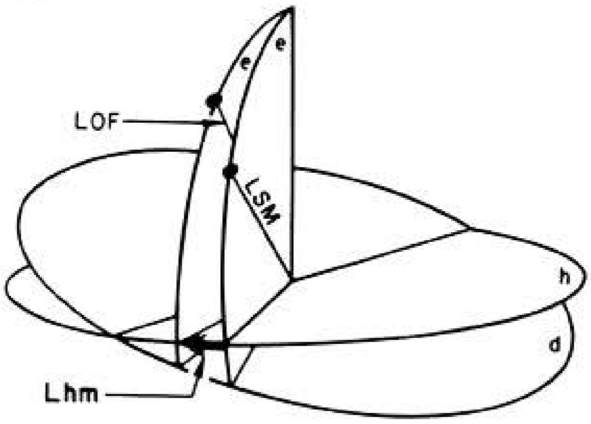
Angle between the normal-to-deck plane through the line of launch and the normal plane through the line of sight to the missile. (***'Ldm'=Bdg'−Bdm'***)



Lhm

Guidance Horizontal Deflection

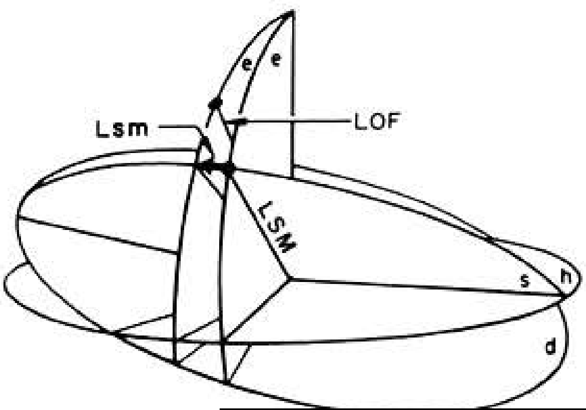
Angle between the vertical plane through the line of sight to the missile and the vertical plane through the line of launch measured in the horizontal plane from the vertical plane through the line of sight to the missile.



Lsm

Guidance Sight Deflection

Angle between the line of sight to the missile and the vertical plane through the line of launch measured from the line of sight to the missile in the slant plane through the line of sight to the missile and through the director elevation axis in the horizontal plane.



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Mb6

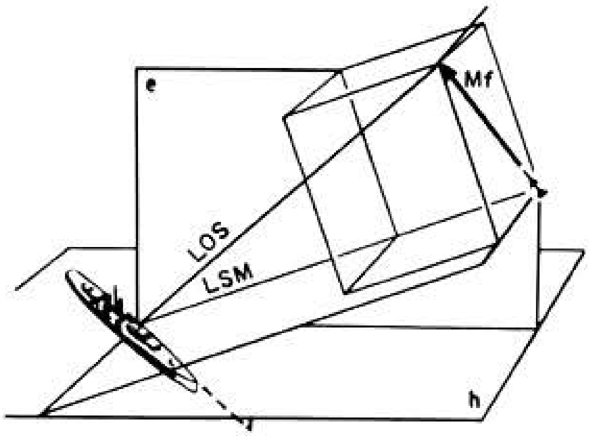
Capture Movement in Bearing

See Note 6 under ***Mb.***

Mf

Missile Linear Offset

Total linear offset of missile, measured from point of capture to line of sight, perpendicularly to line of sight from own ship to missile.



Mfb

Missile Offset Movement in Bearing

Component of ***Mf*** in the horizontal plane perpendicular to the vertical plane through the line of sight.

Mfev

Vertical Missile Offset Movement

Vertical component of ***Mf.***

Mfrh

Missile Offset Movement in Horizontal Range

Component of ***Mf*** in the horizontal plane and in vertical plane through the line of sight.

Mhx6

East-West Horizontal Movement to Capture

See Note 5 under ***Mhx*** in Volume 1.

Mhy6

North-South Horizontal Movement to Capture

See Note 5 under ***Mhy*** in Volume 1.

Mrh6

Capture Movement in Horizontal Range

See Note 6 under ***Mrh*** in Volume 1.

Mv6

Vertical Capture Movement

See Note 6 under ***Mv*** in Volume 1.

M6

Capture Movement

See Note 7 under ***M*** in Volume 1.

mM

Relative Missile Movement

Linear displacement of the target relative to the missile at the time of capture or thereafter.

Note: 1. To express linear displacement of the target relative to the missile due to missile motion, modifier ***m*** is added resulting in symbol ***mMm.***

2. To express linear displacement of the target relative to the missile due to target motion, modifier ***t*** is added resulting in symbol ***mMt.***

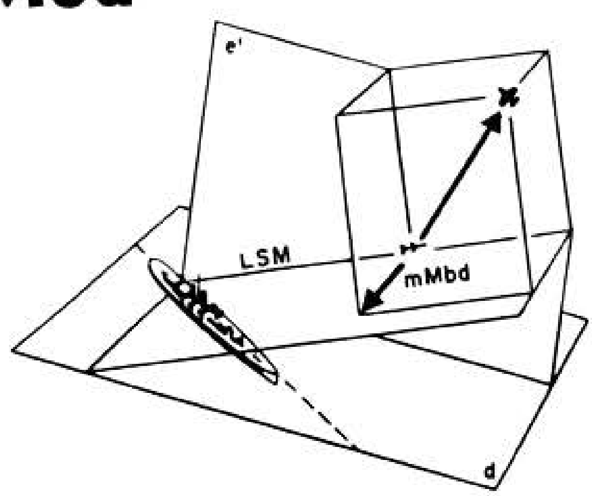
3. To express linear displacement of the target relative to the missile as measured from own ship ***K,*** parentheses and modifier ***o*** are added resulting in symbol ***(mM)o.***

4. To express linear displacement of the target relative to the missile as measured from the missile, parentheses and modifier ***h*** are added resulting in symbol ***(mM)h.***

5. To express linear displacement to aiming position, modifier ***4*** is added resulting in symbol ***mM4.***

6. To express linear displacement of the target relative to the missile measured at the time of capture, modifier ***6*** is added resulting in symbol ***mM6.***

mMbd



Relative Missile Movement in Train

Linear displacement of the target relative to the missile in the deck plane perpendicular to the normal-to-deck plane through the line of sight to the missile.

Note: 1. To express the same quantity due to missile motion, modifier ***m*** is added resulting in symbol ***mMbdm.***

2. To express the same quantity due to target motion, modifier ***t*** is added resulting in symbol ***mMbdt.***

3. To express the same component to aiming position, modifier ***4*** is added and symbol is ***mMbd4.***

4. To express the same component measured at capture, modifier ***6*** is added resulting in symbol ***mMbd6.***

mMbdm

Missile Movement in Train

See Note 1 under ***mMbd***.

mMbd4

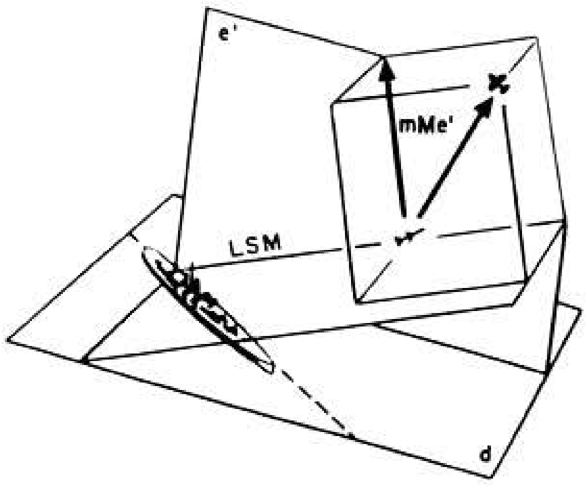
Relative Missile Movement in Train to Aiming Position

See Note 3 under ***mMbd***.

mMe′

Relative Missile Movement in Elevation

Linear displacement of the target relative to the missile perpendicular to the line of sight to the missile in the normal-to-deck plane through the line of sight to the missile.



Note: 1. To express the same quantity due to missile motion, modifier ***m*** is added resulting in symbol ***mMem′***.

2. To express the same quantity due to target motion, modifier ***t*** is added resulting in symbol ***mMet′***.

3. To express the same component measured to aiming position, modifier ***4*** is added resulting in symbol ***mMe4′***.

4. To express the same component measured at capture, modifier ***6*** is added resulting in symbol ***mMe6′***.

mMem′

Missile Movement in Elevation

See Note 1 under ***mMe′***.

mMe4′

Relative Missile Movement in Elevation to Aiming Position

See Note 3 under ***mMe′***.

mMm

Missile Movement

See Note 1 under ***mM***.

mM4

Relative Missile Movement to Aiming Position

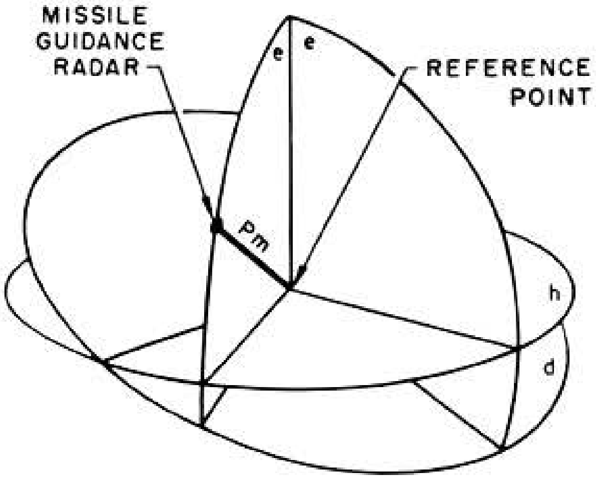
See Note 5 under ***mM***.

mM6

Relative Missile Movement at Capture

See Note 6 under ***mM***.

Pm



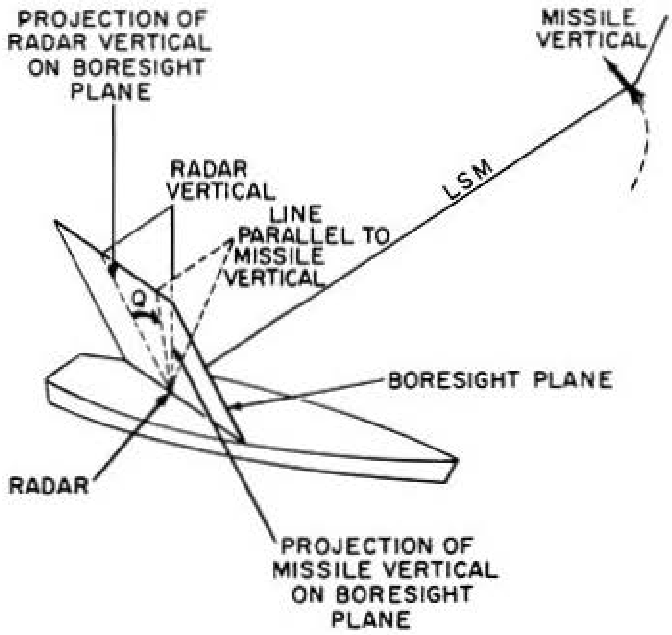
Guidance Parallax Base Length

Total distance from the reference point to the guidance radar measured along the guidance radar parallax base line.

Q

Guidance Phasing Error

Angle between the projection of the guidance radar vertical on the boresight plane and the projection of the missile vertical on the boresight plane measured about the line of sight to the missile. Positive direction is clockwise when viewed along line of sight to the missile.



Q1

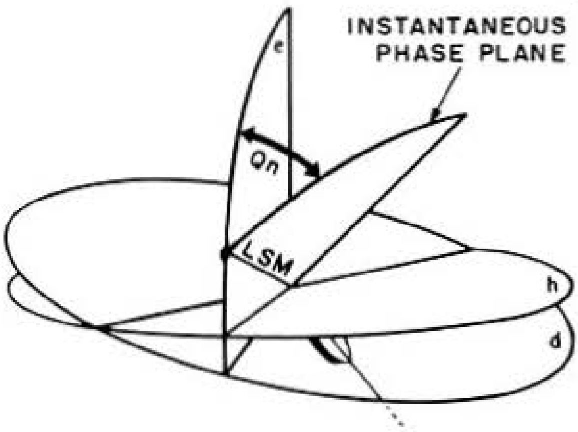
Guidance Phasing Order

Computed guidance phasing error.

Qn

Nutation Phasing Reference

Angle representing instantaneous phase of guidance beam modulation.



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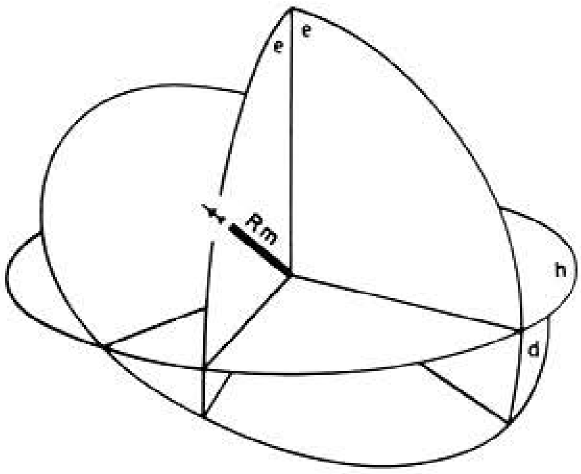
RcosBy

North-South Range Component

Product of present target range by cosine of true target bearing.

Note: 1. This quantity, having no physical definition, is used to designate targets in certain weapons systems.

Rm

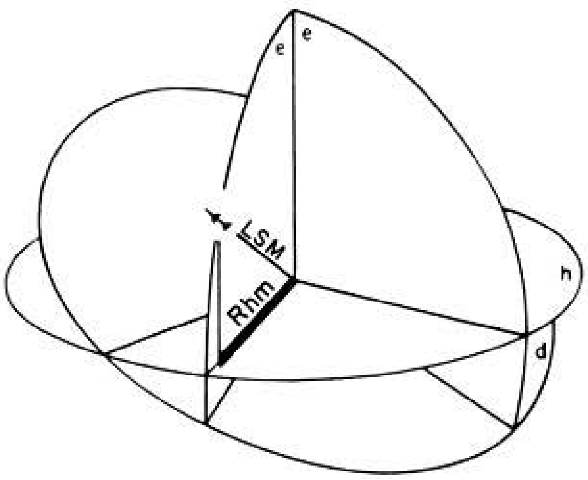


Present Missile Range

Distance from own ship to missile measured along the line of sight to the missile.

Note: 1. To express missile capture range, modifier ***6*** is added and symbol is ***Rm6***.

Rhm

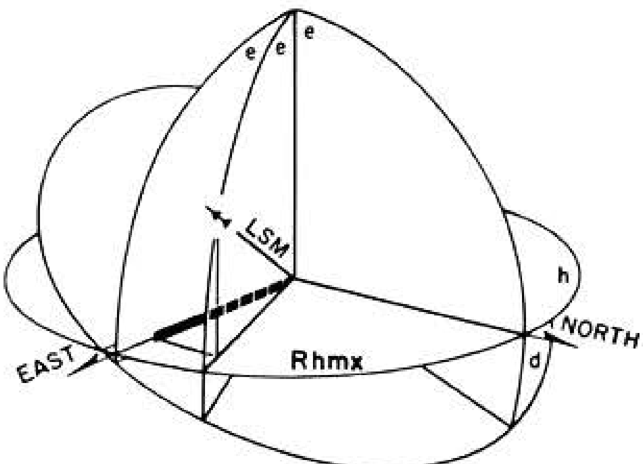


Horizontal Missile Range

Projection of present missile range in the horizontal plane by a vertical plane through the line of sight to the missile.

Note: 1. To express the same component of missile capture range, modifier ***6*** is added and symbol is ***Rhm6***.

Rhmx



Horizontal East-West Missile Range

Component of present missile range in the horizontal plane and in the East-West vertical plane.

Note: 1. To express the same component of missile capture range, modifier ***6*** is added and symbol is ***Rhmx6***.

Horizontal East-West Missile Capture Range

Rhmx6

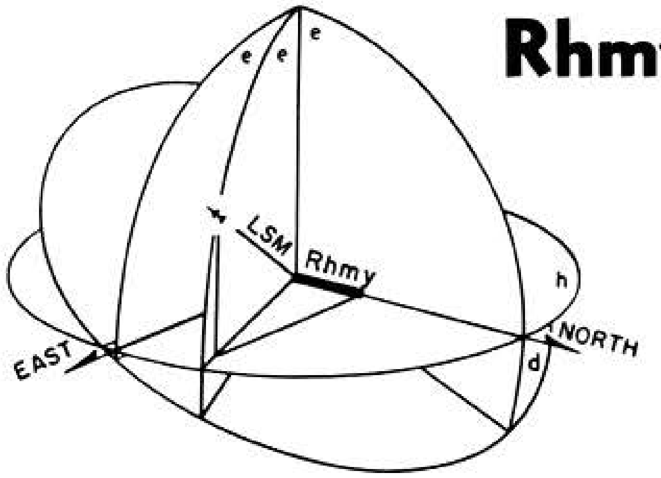
See Note 1 under ***Rhmx.***

Horizontal North-South Missile Range

Rhmy

Component of present missile range in the horizontal plane and in the North-South vertical plane.

Note: 1. To express the same component of missile capture range, modifier ***6*** is added and symbol is ***Rhmy6.***



Horizontal North-South Missile Capture Range

Rhmy6

See Note 1 under ***Rhmy.***

Horizontal Missile Capture Range

Rhm6

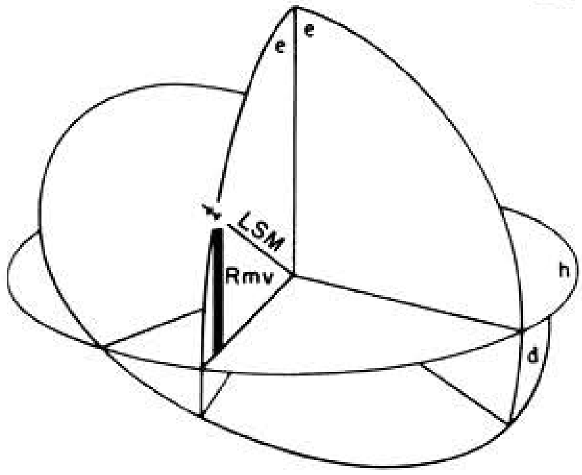
See Note 1 under ***Rhm.***

Rmv

Missile Height

Height of the missile above the horizontal plane measured in the vertical plane through the line of sight to the missile.

Note: 1. To express same component of missile capture range, modifier ***6*** is added and symbol is ***Rmv6.***



Missile Capture Height

Rmv6

See Note 1 under ***Rmv.***

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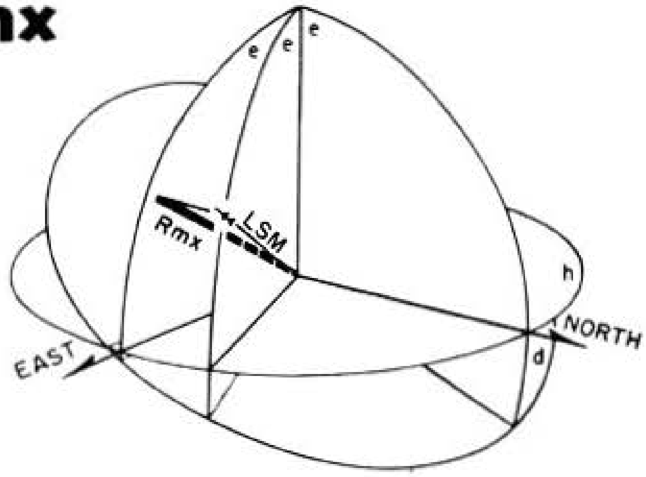
Rmx



East-West Missile Range

Projection of present missile range in the East-West vertical plane.

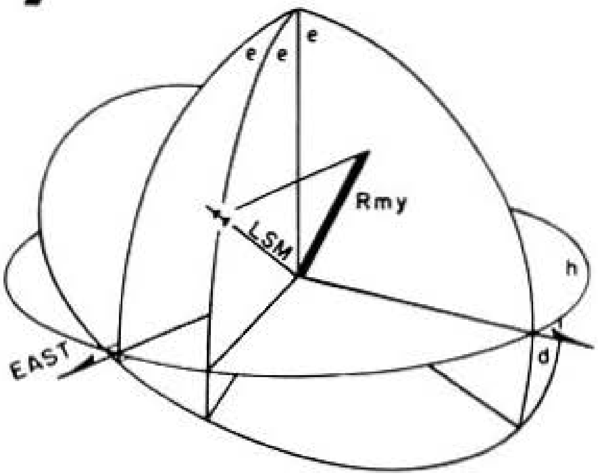
Note: 1. To express same component of missile capture range, modifier *6* is added and symbol is ***Rmx6***.

Rmx6

East-West Missile Capture Range

See Note 1 under ***Rmx***.

Rmy



North-South Missile Range

Projection of present missile range in the North-South vertical plane.

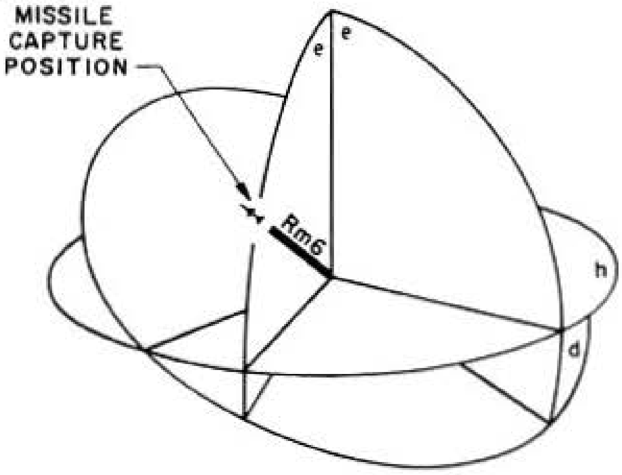
Note: 1. To express the same component of missile capture range, modifier *6* is added and symbol is ***Ry6***.

Rmy6

North-South Missile Capture Range

See Note 1 under ***Rmy***.

Rm6



Missile Capture Range

See Note 1 under ***Rm***.

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Missile Target Range Difference

R-Rm

Scalar difference between present target range and present missile range.

"East-West" Range Component

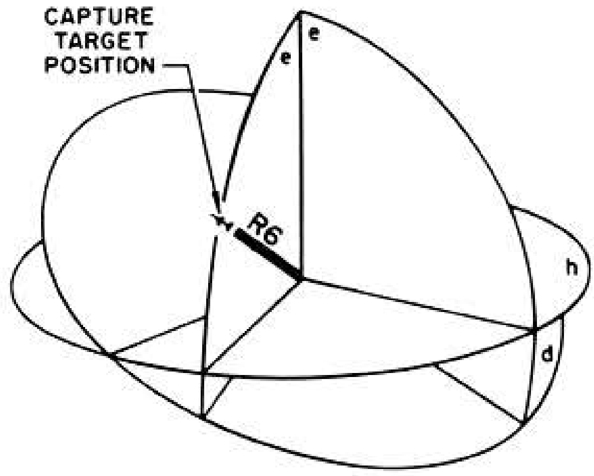
RsinBy

Product of present target range by sine of true target bearing.

Note: 1. This quantity, having no physical definition, is used to designate targets in certain weapons systems.

R6

Distance from own ship to missile position at time of target capture measured along the line of sight to the missile.



Tt

Director Busy Time

Time measured from present during which a director will be occupied with a given target or targets.

T6

Capture Time of Flight

Time of flight of the missile to the missile capture position.

Missile Air Speed

U

Nominal missile speed with respect to the air mass. This speed is independent of the reference frame used for measurement.

Average Velocity to Missile Capture Position

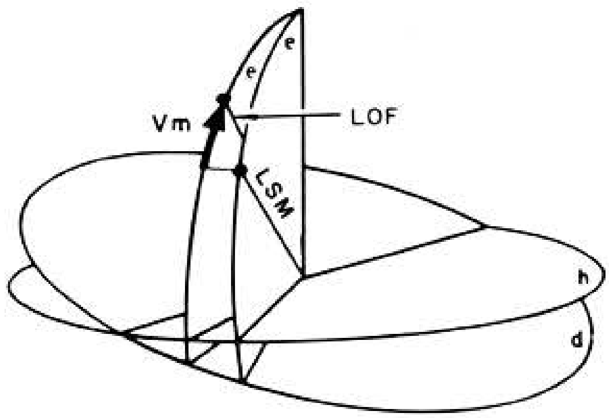
U6

Average velocity of the missile to the missile capture position referred to the frame used by the fire control system.

mUt

Magnitude of vector difference between missile and target velocities immediately before interception.

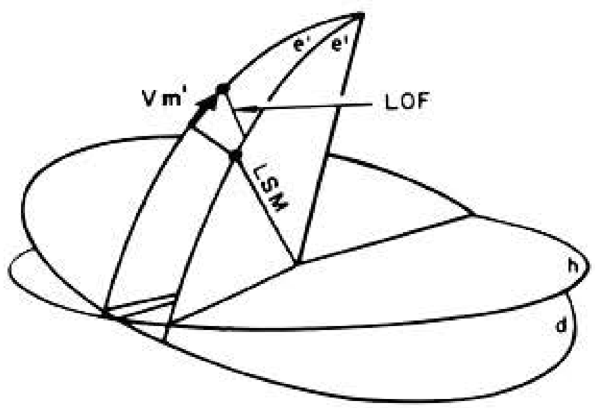
Vm



Guidance Sight Angle

The difference in elevation between the line of launch and the line of sight to the missile, measured in a vertical plane. ($Vm = Edg - Edm$)

Vm′



Guidance Sight Angle

The difference in elevation between the line of launch and the line of sight to the missile, measured in a normal plane. ($Vm' = Edg' - Edm'$)

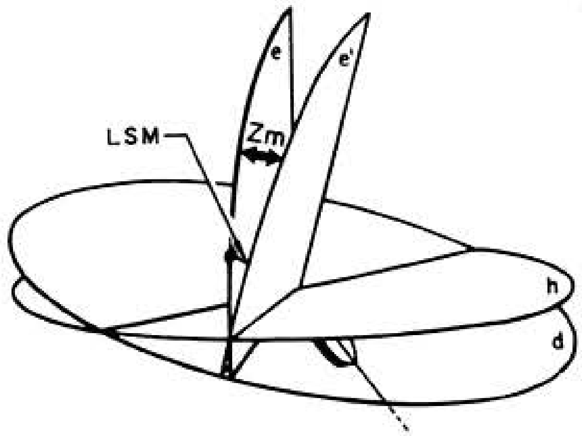
Capture Cross Level — Zd6

See Note 1 under *Zd* in Volume 1.

Guidance Cross Level — Zm

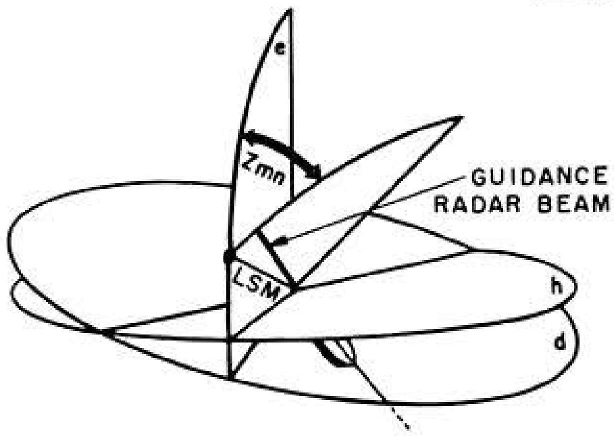
Angle between the vertical plane through the line of sight to the missile and the normal-to-deck plane through the intersection of the vertical plane through the line of sight to the missile measured about the axis which is the intersection of the vertical plane through the line of sight to the missile and the horizontal plane. Positive direction is clockwise when viewed along axis inward from target.

Note: 1. To express the same quantity at the time of capture, modifier *6* is added and symbol is *Zm6*.



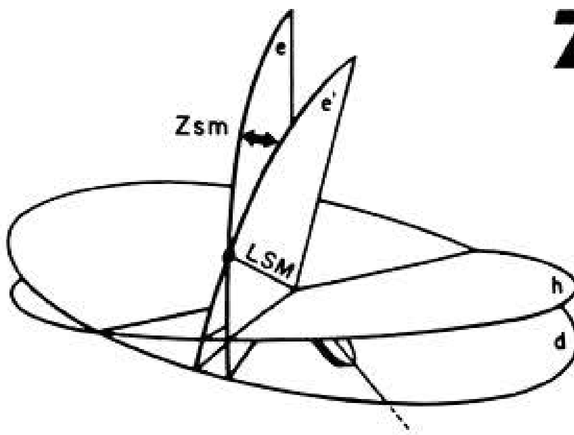
Nutation Cross Traverse (Guidance Radar) — Zmn

Angle between the vertical plane through the line of sight to the missile and the plane through the instantaneous position of the nutating radar beam and the line of sight to the missile measured about the line of sight to the missile. Positive direction is clockwise when viewed along axis inward from missle.



Guidance Cross Traverse — Zsm

Angle between the vertical plane through the line of sight to the missile and the normal through the line of sight to the missile measured about the line of sight to the missile. Positive direction is clockwise when viewed along axis inward from the missile.



Guidance Cross Level at Capture — Zm6

See Note 1 under *Zm.*

Capture Roll — Zo6

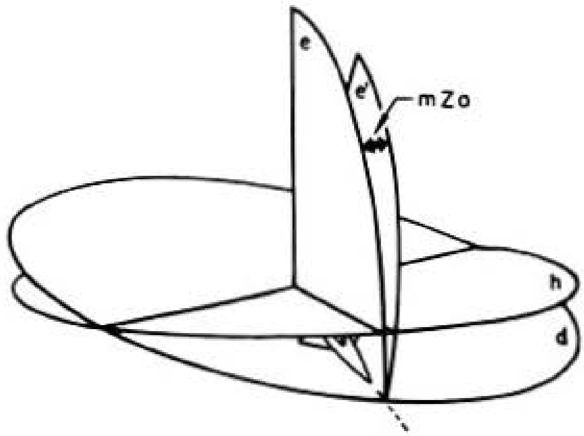
See Note 2 under *Zo* in Volume 1.

Zs6

Capture Cross Traverse

See Note 1 under ***Zs*** in Volume 1.

mZo



Missile Roll

Angle between the vertical plane through the missile centerline and the normal-to-deck plane through the missile centerline, measured about the missile centerline. Positive direction is clockwise when viewed inward from the missile bow.

mZo1

Missile Roll Order

Launching bias applied to missile vertical reference.

Appendix A

BASIC SYMBOLS

Symbol	Name	Meaning when used alone
A		
B	Bearing of LOS	The relative bearing of the target measured from the vertical plane through own ship centerline to the vertical plane through the line of sight in the horizontal plane clockwise from own ship centerline.
Bm	Bearing of LSM	The relative bearing of the missile measured from the vertical plane through own ship centerline to the vertical plane through the line of sight to the missile in the horizontal plane clockwise from own ship centerline.
mB	Bearing of LMT	The relative bearing of the target measured from the vertical plane through the missile centerline to the vertical plane through the missile line of sight in the horizontal plane clockwise from the missile centerline.
C	Course of target from own ship	The course of the target from the north-south vertical plane to the vertical plane through the relative target speed vector in the frame used by the fire control system, measured in the horizontal plane clockwise from north.
Cm	Course of missile from own ship	The course of the missile from the north-south vertical plane to the vertical plane through the missile speed vector relative to own ship in the frame used by the fire control system, measured in the horizontal plane clockwise from north.
mC	Course of target from missile	The course of the target from the north-south vertical plane to the vertical plane through the target speed vector relative to the missile in the frame used by the fire control system, measured in the horizontal plane clockwise from north.
D	Rate of	The differentiating operator d/dt.
E	Elevation of LOS	The elevation of the target above the horizontal plane measured upward from the horizontal plane in the vertical plane through the line of sight.
Em	Elevation of LSM	The elevation of the missile above the horizontal plane measured upward from the horizontal plane in the vertical plane through the line of sight to the missile.
mE	Elevation of LMT	The elevation of the target above the horizontal plane measured upward from the horizontal plane in the vertical plane through the missile line of sight.
Ei	Level from LOS	The angle between horizontal plane and the deck plane, measured downward from the horizontal plane (on the target side of own ship) in the vertical plane through the line of sight.

Appendix A—Continued

Symbol	Name	Meaning when used alone
Eim	Level from LSM	The angle between the horizontal plane and the deck plane, measured downward from the horizontal plane (on the missile side of own ship) in the vertical plane through the line of sight to the missile.
mEi	Level from LMT	The angle between the horizontal plane and the missile deck plane, measured downward from the horizontal plane (on the target side of the missile) in the vertical plane through the missile line of sight.
F	Missile offset angle	The angle between the line of sight to the missile and the line of sight.
G	Gyro angle	(See Underwater Related Quantities, volume 2.)
mG	Crossing angle	The angle between the line of sight and the missile velocity vector.
H		
I	Angle of inclination	Only useful as a rate. ***DI*** expresses the rate of rotation of own ship with respect to the earth frame.
mI	Angle of missile inclination.	Only useful as a rate. ***DmI*** expresses the rate of rotation of the missile with respect to the earth frame.
K	Arbitrary constant	
L	Sight deflection from LOS	The total lead angle between the line of sight and the line of fire.
Lm	Sight deflection from LSM.	The total lead angle between the line of sight to the missile and the line of fire.
M	Linear movement	The total linear displacement of the target during the time of flight due to relative motion between own ship and target in the frame used by the fire control system.
mM	Relative guidance displacement.	The total linear displacement of the target during a given time with respect to missile.
P	Launcher parallax base length.	The total linear displacement between the reference point and the launcher measured along the launcher parallax base line.
Pm	Guidance radar parallax base length.	The total linear displacement between the reference point and the guidance radar measured along the guidance radar parallax base line.
Ps	Tracking radar parallax base length.	The total linear displacement between the reference point and the tracking radar measured along the tracking radar parallax base line.

Appendix A—Continued

Symbol	Name	Meaning when used alone
Q	Radar phasing order	The angle between the projection of the guidance radar vertical on the boresight plane and the projection of the missile vertical on the boresight plane measured about the line of sight to the missile.
R	Range along LOS	The distance between own ship and target measured along the line of sight.
Rm	Range along LSM	The distance between own ship and missile measured along the line of sight to the missile.
mR	Range along LMT	The distance between missile and target measured along the line of sight from missile to target.
S		
T	Time	Elapsed time.
U	Speed	The nominal speed of the missile with respect to the air mass.
V	Sight angle from LOS	The difference in elevation between the line of sight and the line of fire measured in a vertical plane.
Vm	Sight angle from LSM	The difference in elevation between the line of sight to the missile and the line of fire measured in a vertical plane.
W	Wind rate	The total rate of the true wind measured with respect to the earth.
Z	Cross level about LOS	Angle between the vertical plane through the line of sight, and the normal-to-deck plane through the intersection of the vertical plane through the line of sight and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the line of sight and the horizontal plane.
Zm	Cross level about LSM	The angle between the vertical plane through the line of sight to the missile, and the normal-to-deck plane through the intersection of the vertical plane through the line of sight to the missile and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the line of sight to the missile and the horizontal plane.
mZ	Cross level about LMT	The angle between the vertical plane through the missile line of sight, and the normal-to-missile-deck plane through the intersection of the vertical plane through the missile line of sight and the horizontal plane, measured about an axis which is the intersection of the vertical plane through the missile line of sight and the horizontal plane.

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Appendix B

BASIC SYMBOL MODIFIERS

Modifier	Name	Used to indicate
a	Apparent or athwarthship	Quantities expressing rates and angles of apparent wind, or athwartship components of parallax or range.
b	Bearing	Quantities in direction affecting bearing.
c	Computed	Quantities as computed.
d	Deck	Quantities measured in, from, or about axes in the deck.
e	Elevation	Quantities in direction affecting elevation.
f	Flight	Quantities related to weapon flight through the air.
g	Launcher	Quantities measured from, to, or about line of launch or launcher.
h	Horizontal	Quantities measured in horizontal plane.
i		
i		
k	Earth	Quantities expressing earth rates, or measured with respect to the earth.
l		
m	Missile	As a suffix to a basic symbol, quantities measured from, to, or about line of sight to the missile or guidance radar; as a prefix to a basic symbol, quantities measured from missile, to or from or about missile line of sight.
n	Nutational	Quantities relating to the nutation of the radar beam.
o	Own ship	Quantities measured from, to, along, or about own ship or missile centerline, and quantities expressing own ship or missile rates, when used with appropriate prefix.
p	Prediction	
q	Heading	The compass head of own ship, missile, or target.
r	Range	Quantities in direction affecting range.

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Appendix B—Continued

Modifier	Name	Used to indicate
s	Line of sight	Quantities measured from, to, or about line of sight or tracking radar.
t	Target	Quantities measured from, to, or about target centerline and quantities expressing target rates.
u		
v	Vertical	Quantities in vertical direction.
w	Wind	Quantities related to wind.
x	East-West	Quantities measured in East-West direction.
y	North–South	Quantities measured from North or in North–South direction.
z	Cross level	Quantities related to cross level.
'	Prime	Before quantity, measurement from a normal-to-deck or-to-missile-deck plane; after quantity, measurement to or in a normal plane.
''	Double Prime	Before quantity, measurement from a plane normal to the slant plane; after quantity, measurement to or in a plane normal to the slant plane.
1	Order	Ordered quantities.
2	Future position	Quantities measured with respect to future target position.
3	Launching Position	Quantities measured at instant of launch.
4	Aiming position	Quantities measured with respect to aiming position.
5	Fuze	Quantities used in fuze computations.
6	Capture position	Quantities measured with respect to capture target position or missile capture position, or at time of capture.
(())	Double parentheses	Quantities measured in a system of three indeterminate coordinates.

Appendix C

QUANTITY MODIFIERS

These modifiers are used before or after parentheses.

Modifier	Name	Before the parentheses	After the parentheses
a			
b	Ballistic	The portion of the quantity accounting for superelevation or drift.	The quantity corrected for the effect of superelevation or drift.
c	Computed, generated, or smoothed	The value of a quantity as computed or generated in the mechanism.	The value of a quantity as smoothed in the mechanism.
d	Designated	The designated value of the quantity.	No meaning.
e	Error	An error of the quantity.	No meaning.
f	Function	A function of the quantity.	No meaning.
g	Dead time	The correction to the quantity due to dead time.	The quantity corrected for the effect of dead time.
h	Missile	No meaning.	The quantity referred to a frame rigidly attached to the missile.
i	Increment	An increment of the quantity.	No meaning.
i	Computational addition or partial	A computational addition to the quantity.	A partial value of the quantity.
k	Earth	No meaning.	The quantity referred to the earth frame.
l	Initial	The initial value of the quantity.	No meaning.
m	Relative motion	The portion of that quantity accounting for relative motion between own ship and target.	The quantity corrected for effect of relative motion between own ship and target.
mg	Crossing angle	The portion of that quantity accounting for angular velocity of the line of sight to missile.	The quantity corrected for the effect of angular velocity of the line of sight to the missile.

Appendix C—Continued

Modifier	Name	Before the parentheses	After the parentheses
n			
o	Observed or measured	The observed or measured value of the quantity.	Referred to a frame rigidly attached to own ship.
p	Launcher parallax	The portion of the quantity accounting for launcher parallax.	The quantity corrected for the effect of the launcher parallax.
pm	Guidance beam parallax	The portion of the quantity accounting for guidance beam parallax.	The quantity corrected for the effect of guidance beam parallax.
ps	Tracking director parallax	The portion of the quantity accounting for tracking director parallax.	The quantity corrected for effect of tracking director parallax.
q	Corrective input, spot, or bias	A correcting input, spot, or bias to the quantity.	No meaning.
r	Rotational	The correction to a quantity due to launcher rotational velocity.	The quantity including the correction for launcher rotational velocity.
s	Selected	A selected value of the quantity.	Referred to the inertial frame.
t	Translational	The correction to a quantity due to launcher translational velocity.	The quantity including the correction for launcher translational velocity.
u	Unclear	Angular or other coordinates not clear for various reasons (left angle limit).	Angular or other coordinates not clear for various reasons (right angle limit).
v			
w	Wind	The portion of the quantity accounting for the effect of the wind.	The quantity corrected for the effect of the wind.
x			
y			
z			

Appendix D

LIST OF RELATED QUANTITIES

Appendix D—Continued

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